Experimental Results

1) General scheme

1.1) Procedures:

In this new experiment, three cars were used, with different arrangements and speeds between 30 Km/h and 70 Km/h. Basically, we performed tests with 1, 2 or 3 cars, varying the speed and spacing between vehicles. In addition, we use two types of path orientation, starting at 0 or 180 degrees.

For audio recordings, we used an arrangement of five crossed 20cm microphones, but one of them presented a defect, as shown in the figure below:

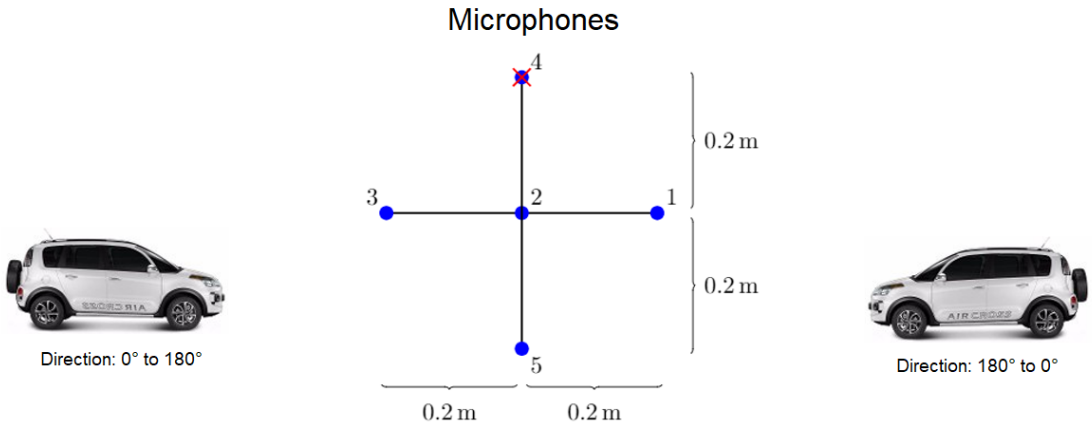


Figure 1.1.1: front view of microphones arrangement and two possible directions of cars. The microphone number 4 presented problems.

The arrangement of microphones was placed on the edge of the sidewalk at a height of 1.26m, 4.3m away from the center of the street. The wheels of the vehicles passed 70 cm from the center. As follow, some important measures:

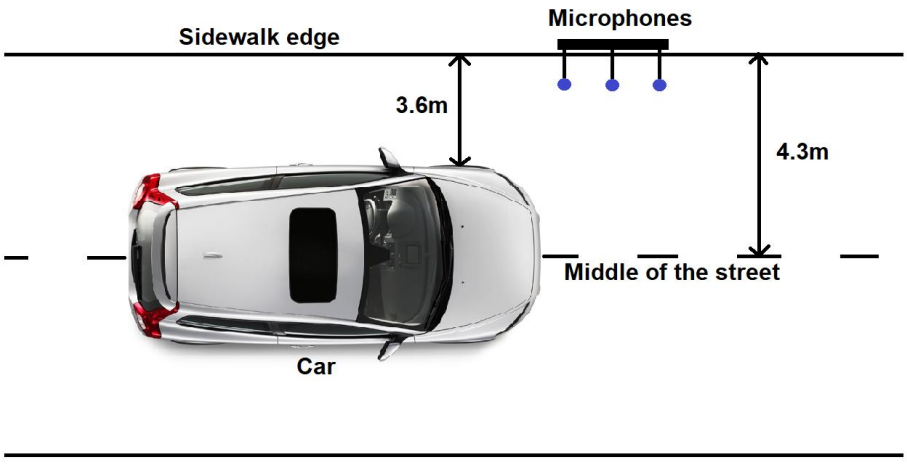


Figure 1.1.2: top view of car and street.

1.2) Tests:

Now let's consider three cars (IDs: 1, 2, 3), with which 10 different tests were performed. Below are tables containing data on wheel and vehicles spacing, numbers of cars, gearbox type, speeds and directions used:

Test	Speed (Km/h)	Number of cars	ID	Spacing	Orientation
1	30	2	**1, 2**	*Short*	180° to 0°
2	30	2		*Long*	0° to 180°
3	40	2		*Short*	180° to 0°
4	40	2		*Long*	0° to 180°
5	50	2		*Short*	180° to 0°
6	50	2		*Long*	0° to 180°
7	60	2		*Short*	180° to 0°
8	60	3	**1, 2, 3**	*Short*	180° to 0°
9	60	3		*Long*	180° to 0°
10	70	1	**1**	------	180° to 0°

Figure 1.2.1: some data about the tests.

Car	1	2	3
Wheels spacing (m)	2.70	2.57	2.45
Gearbox type	*Automatic*	*Automatic*	*Manual*

Figure 1.2.2: some characteristics of the cars.

This information was useful to outline the theoretical behavior of DOA, as we will see soon in the graphs.

2) Experiment

2.1) Analysis:

Basically, four methods were applied to the data collected: generalized cross-correlation with phase transform (GCC-PHAT), adaptive eigenvalue decomposition (AEVD), interaural time differences (ITD) and fast block LMS (FLMS). However, only the GCC-PHAT algorithm performed well, as shown in the graphs.

For each test, we obtain the following graphs: spectrogram, DOA (estimated and theoretical), power spectrum (moment of passage of the vehicle by 90 degrees) and energy over time. For this case, we used the horizontal microphones 1 and 2.

- Test 1 – Velocity: 30 Km/h – Orientation: 180° to 0°

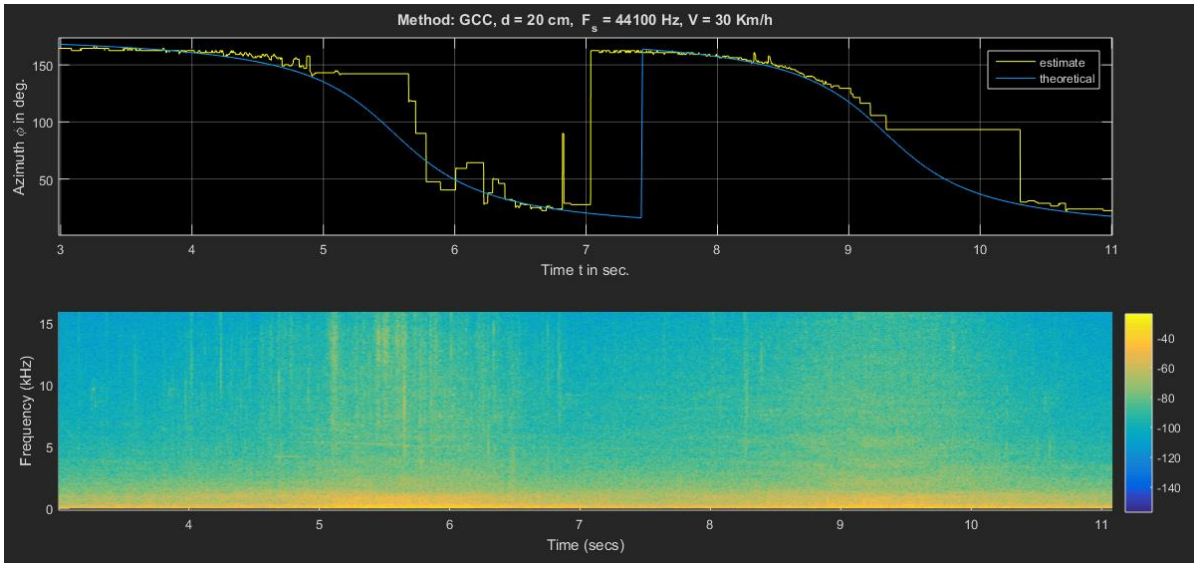


Figure 2.1.1.a: above, comparison between the theoretical azimuth and its estimation, and below, the spectrogram for the full band signal (cars 1 and 2 respectively).

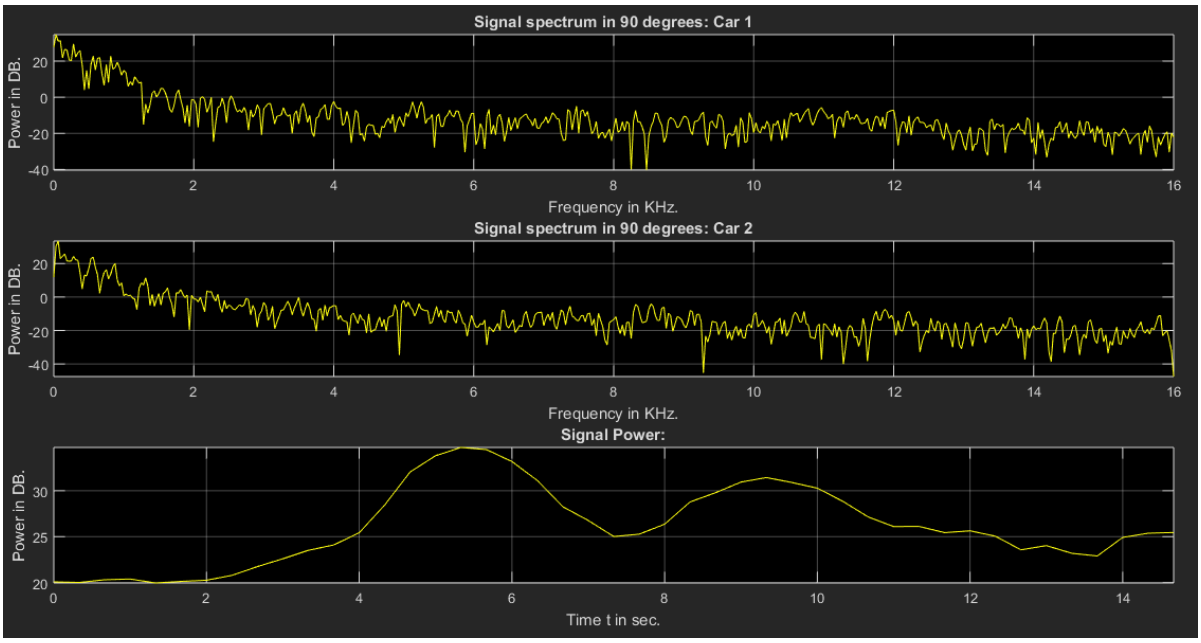


Figure 2.1.1.b: above, in the first two, the power spectrum of each vehicle by 90 ° and below, in the third, the energy over time.

- Test 2 – Velocity: 30 Km/h – Orientation: 0° to 180°

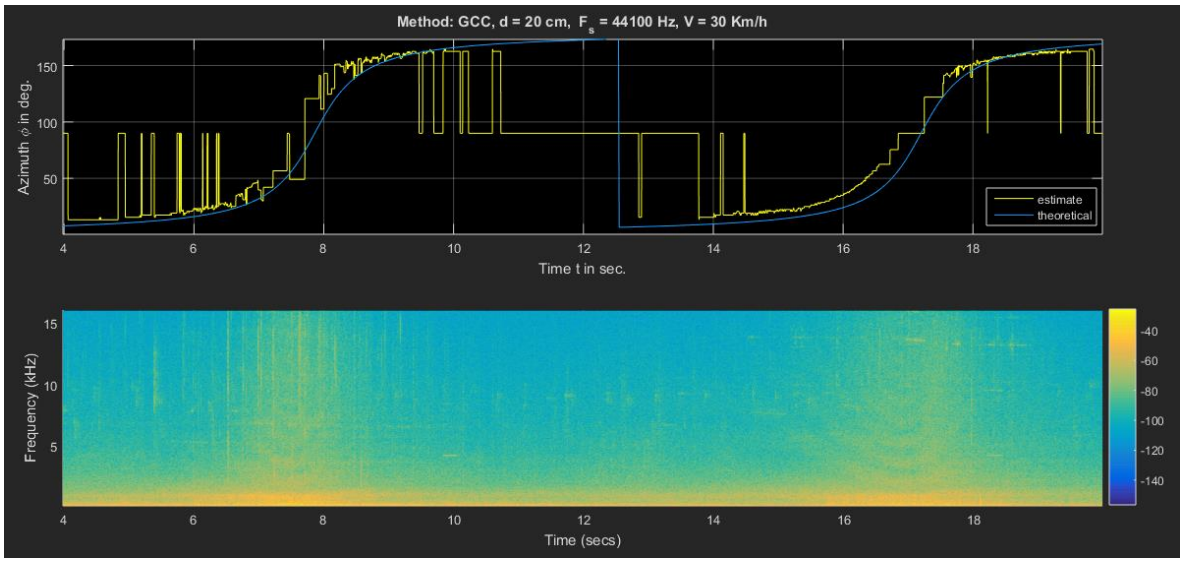


Figure 2.1.2.a: above, comparison between the theoretical azimuth and its estimation, and below, the spectrogram for the full band signal (cars 1 and 2 respectively).

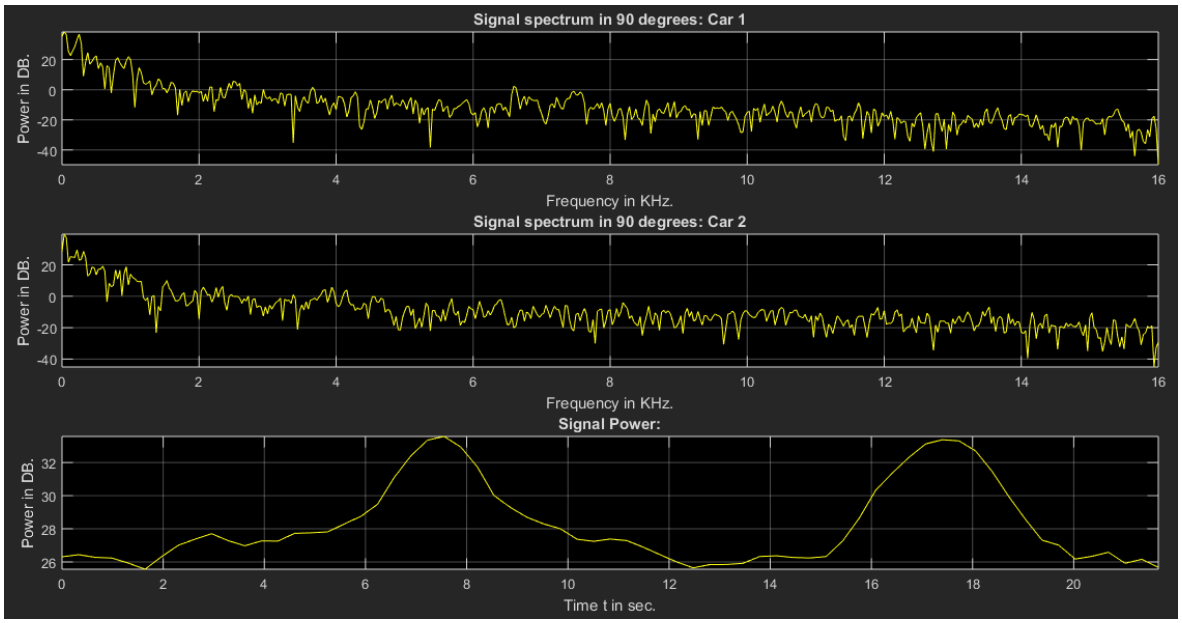


Figure 2.1.2.b: above, in the first two, the power spectrum of each vehicle by 90 ° and below, in the third, the energy over time.

- Test 3 – Velocity: 40 Km/h – Orientation: 180° to 0°

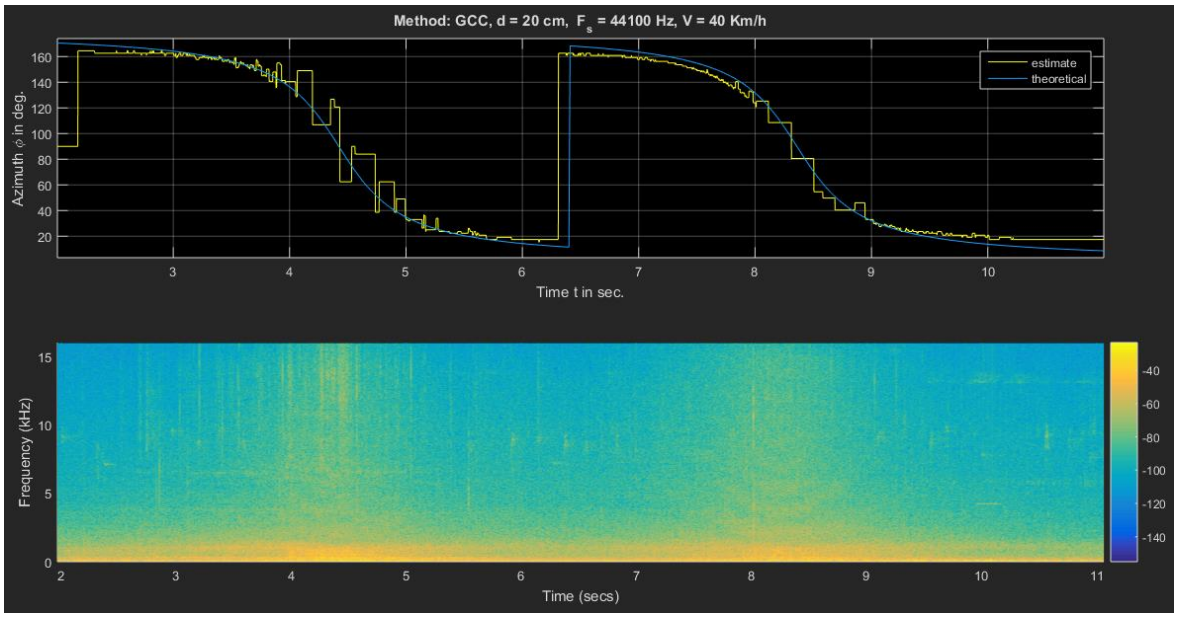


Figure 2.1.3.a: above, comparison between the theoretical azimuth and its estimation, and below, the spectrogram for the full band signal (cars 1 and 2 respectively).

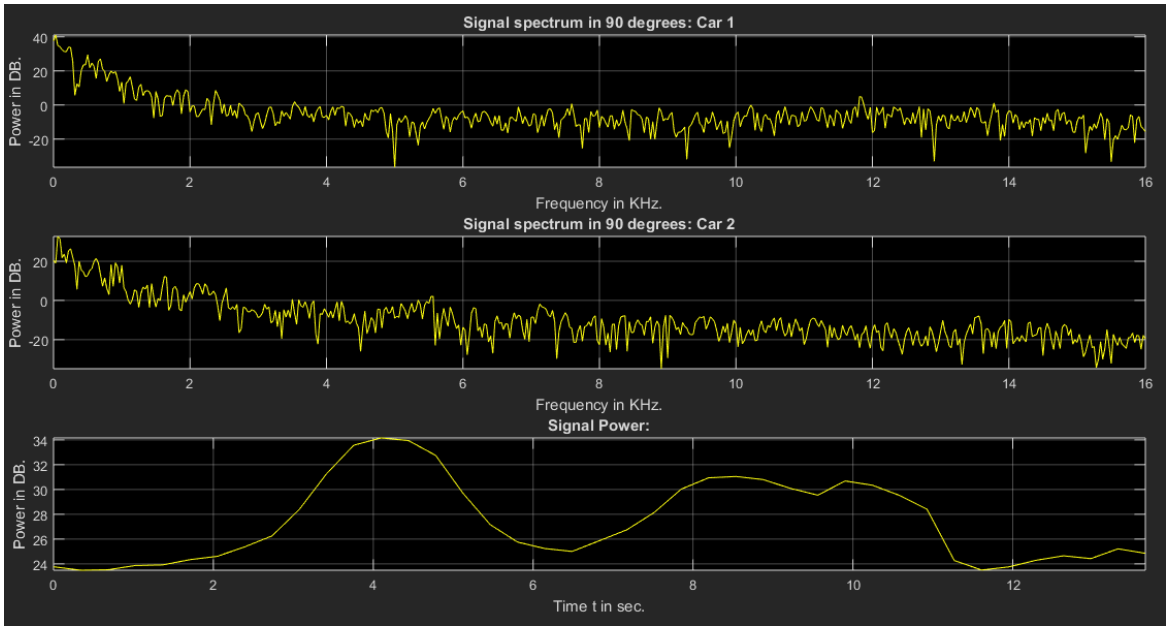


Figure 2.1.3.b: above, in the first two, the power spectrum of each vehicle by 90 ° and below, in the third, the energy over time.

- Test 4 – Velocity: 40 Km/h – Orientation: 0° to 180°

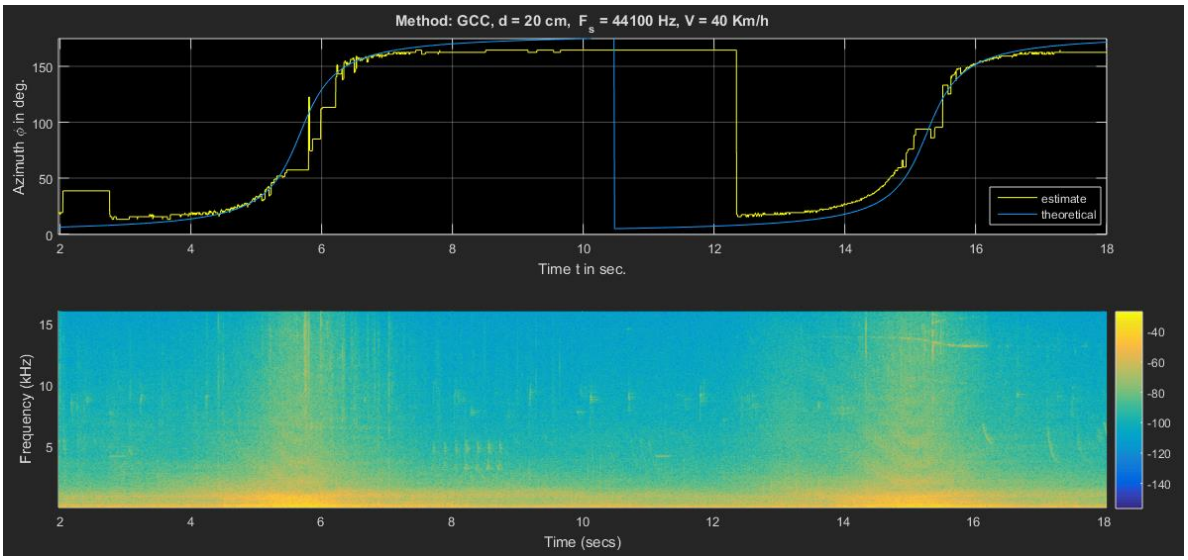


Figure 2.1.4.a: above, comparison between the theoretical azimuth and its estimation, and below, the spectrogram for the full band signal (cars 1 and 2 respectively).

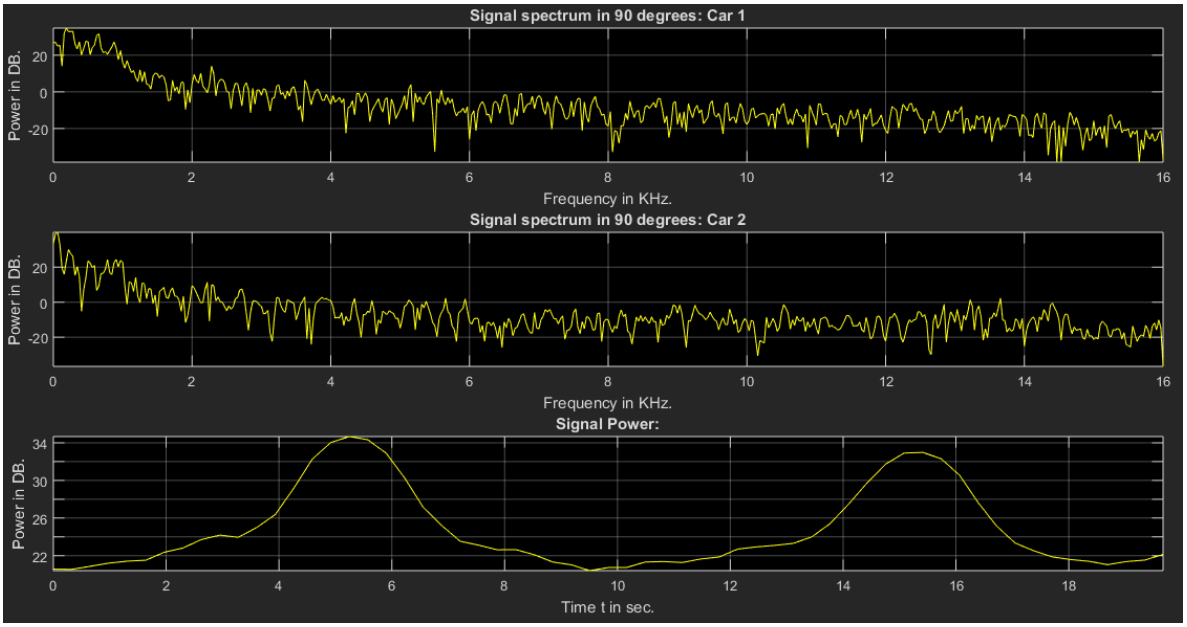


Figure 2.1.4.b: above, in the first two, the power spectrum of each vehicle by 90 ° and below, in the third, the energy over time.

- Test 5 – Velocity: 50 Km/h – Orientation: 180° to 0°

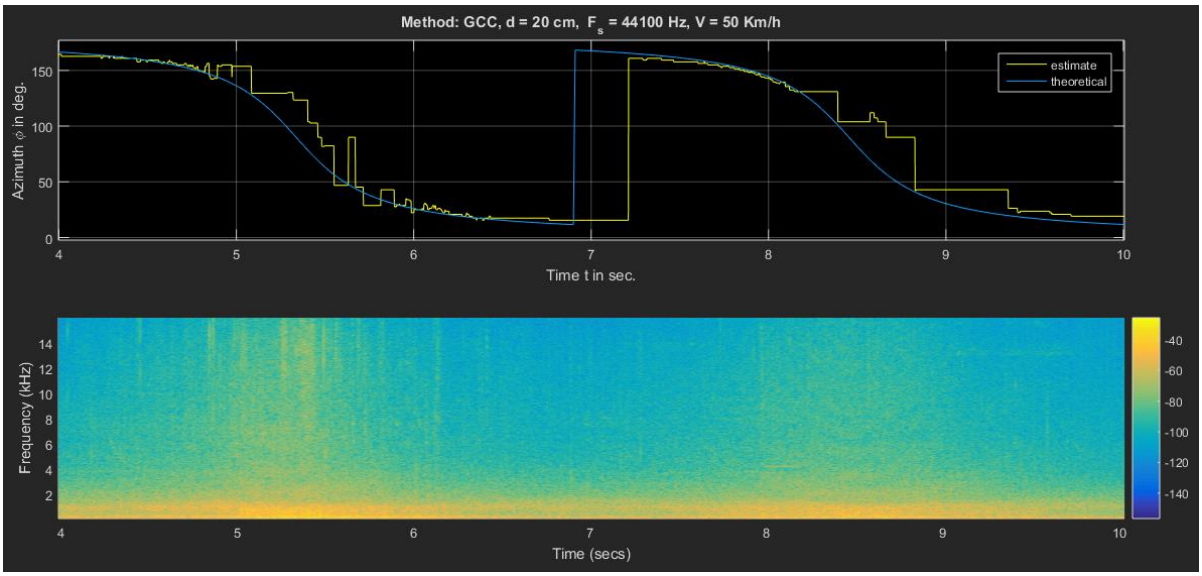


Figure 2.1.5.a: above, comparison between the theoretical azimuth and its estimation, and below, the spectrogram for the full band signal (cars 1 and 2 respectively).

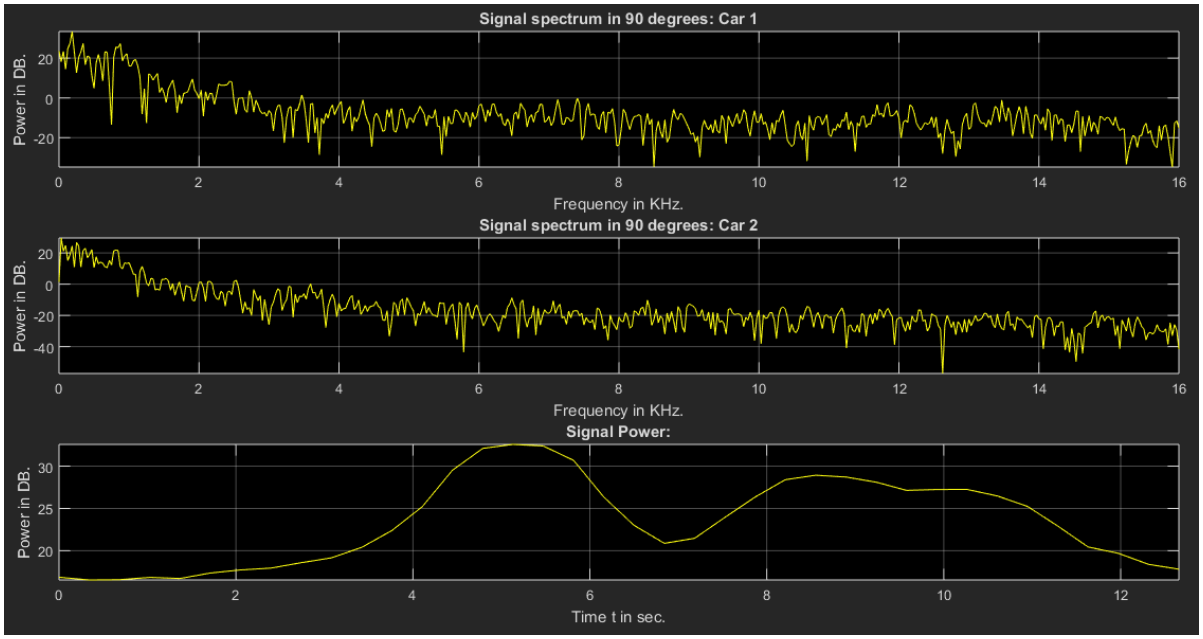


Figure 2.1.5.b: above, in the first two, the power spectrum of each vehicle by 90 ° and below, in the third, the energy over time.

- Test 6 – Velocity: 50 Km/h – Orientation: 0° to 180°

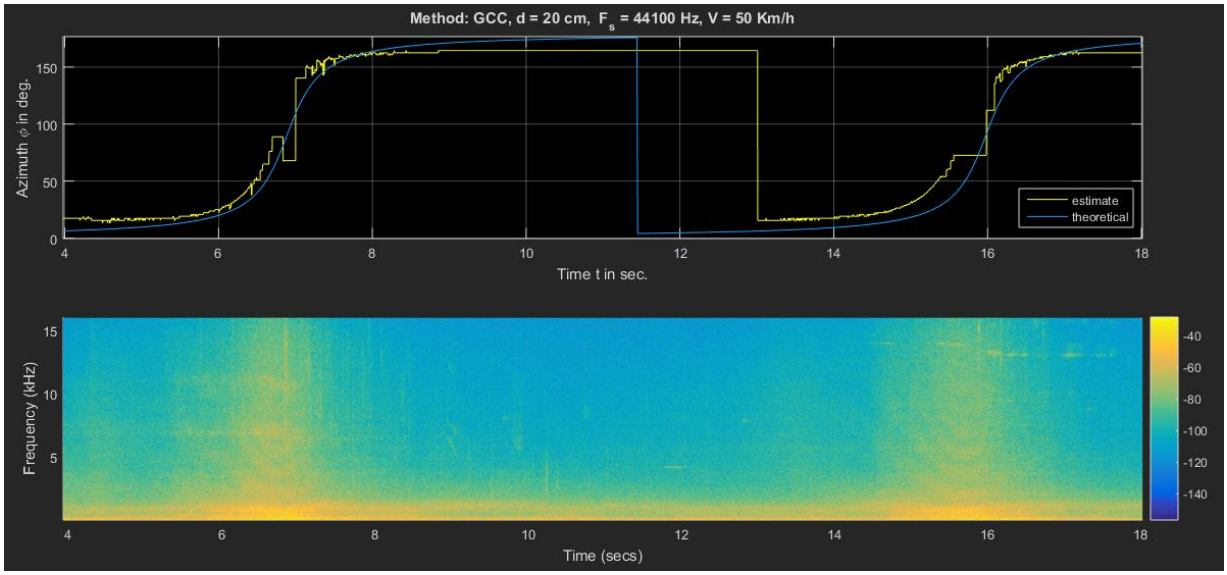


Figure 2.1.6.a: above, comparison between the theoretical azimuth and its estimation, and below, the spectrogram for the full band signal (cars 1 and 2 respectively).

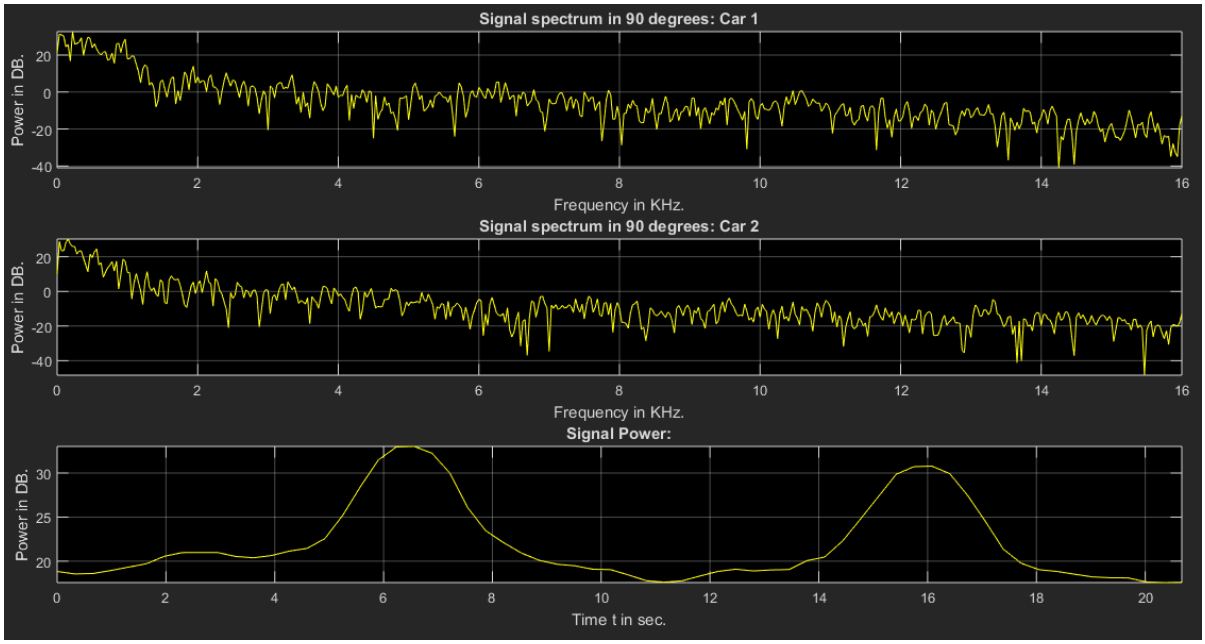


Figure 2.1.6.b: above, in the first two, the power spectrum of each vehicle by 90 ° and below, in the third, the energy over time.

- Test 7 – Velocity: 60 Km/h – Orientation: 180° to 0°

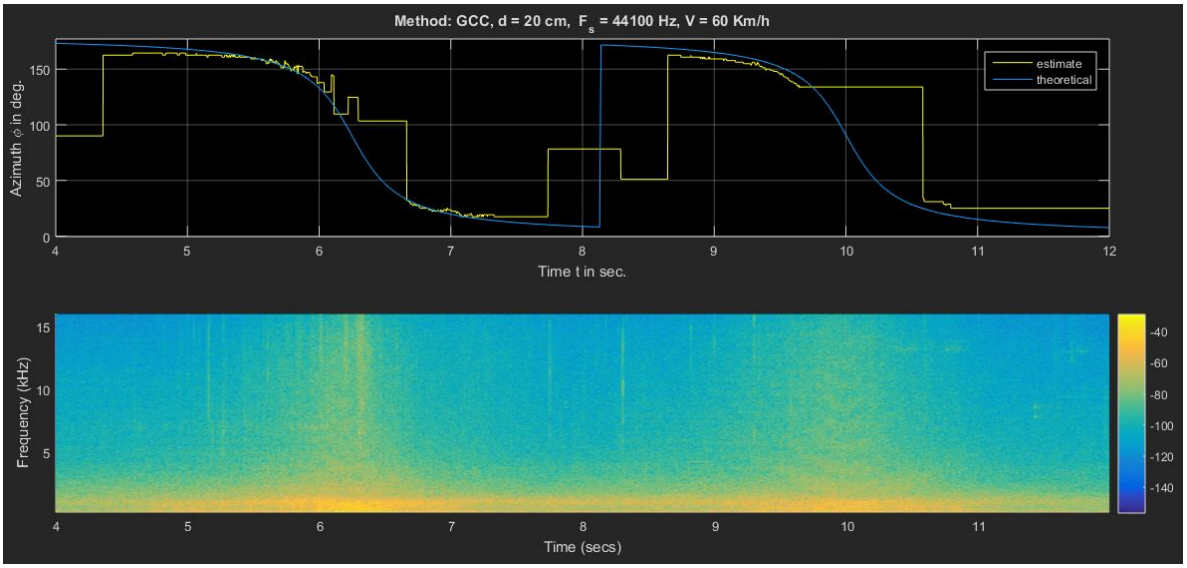


Figure 2.1.7.a: above, comparison between the theoretical azimuth and its estimation, and below, the spectrogram for the full band signal (cars 1 and 2 respectively).

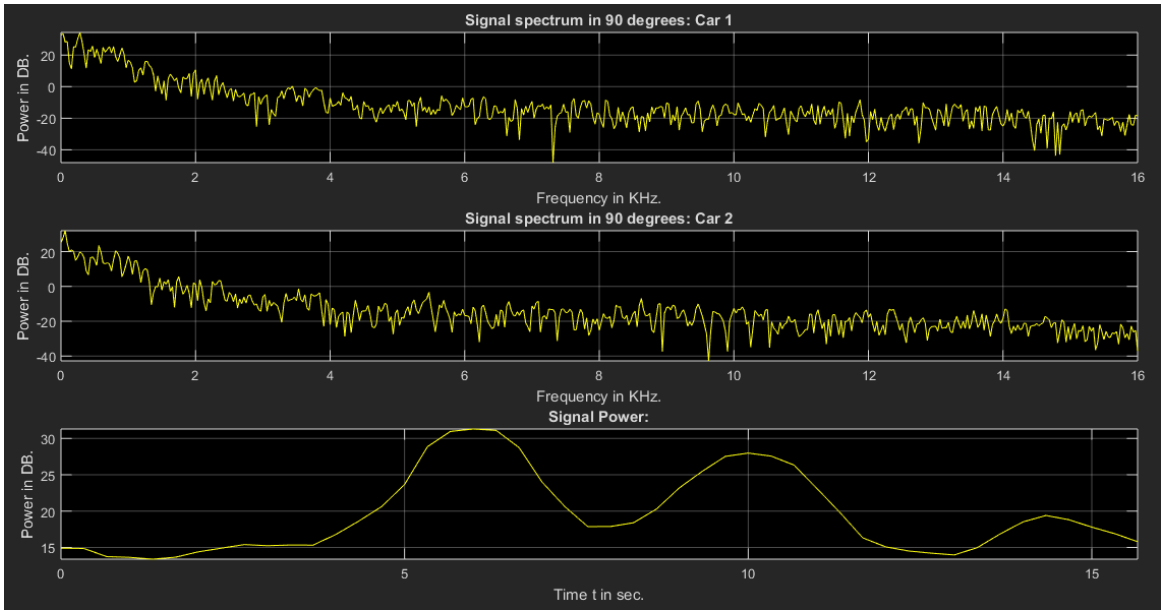


Figure 2.1.7.b: above, in the first two, the power spectrum of each vehicle by 90 ° and below, in the third, the energy over time.

- Test 8 – Velocity: 60 Km/h – Orientation: 180° to 0°

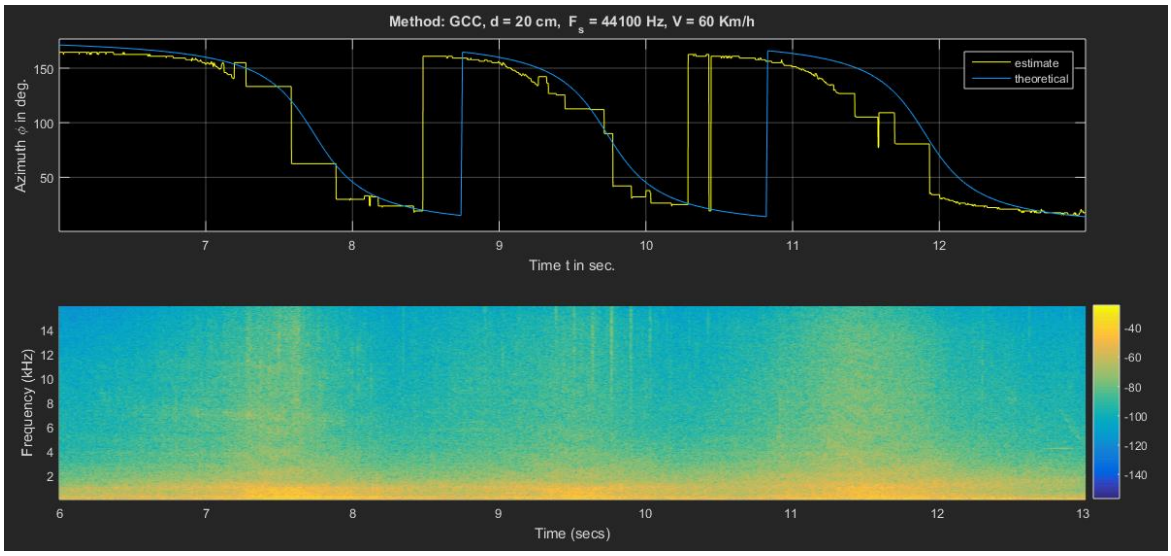


Figure 2.1.8.a: above, comparison between the theoretical azimuth and its estimation, and below, the spectrogram for the full band signal (cars 1, 2 and 3 respectively).

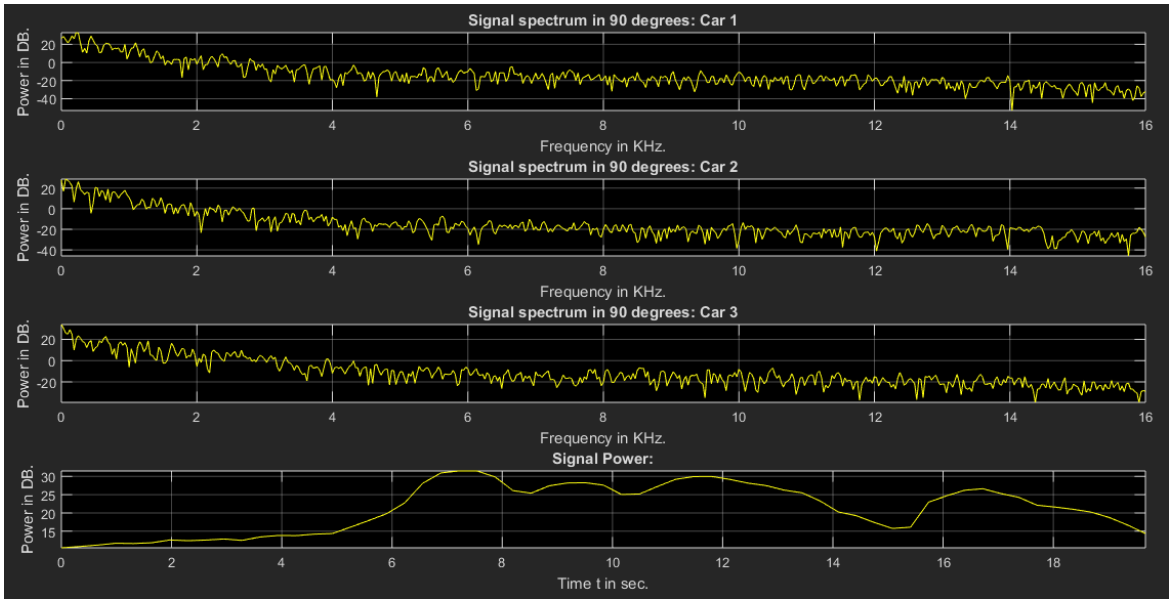


Figure 2.1.8.b: above, in the first three, the power spectrum of each vehicle by 90 ° and below, in the fourth, the energy over time.

- Test 9 – Velocity: 60 Km/h – Orientation: 180° to 0°

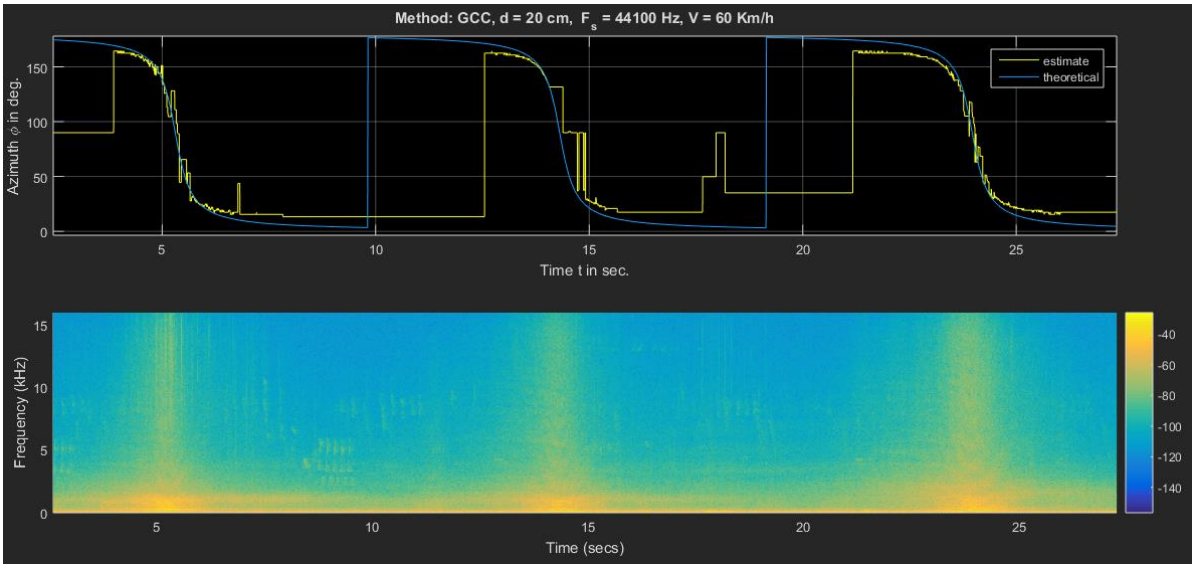


Figure 2.1.9.a: above, comparison between the theoretical azimuth and its estimation, and below, the spectrogram for the full band signal (cars 1, 2 and 3 respectively).

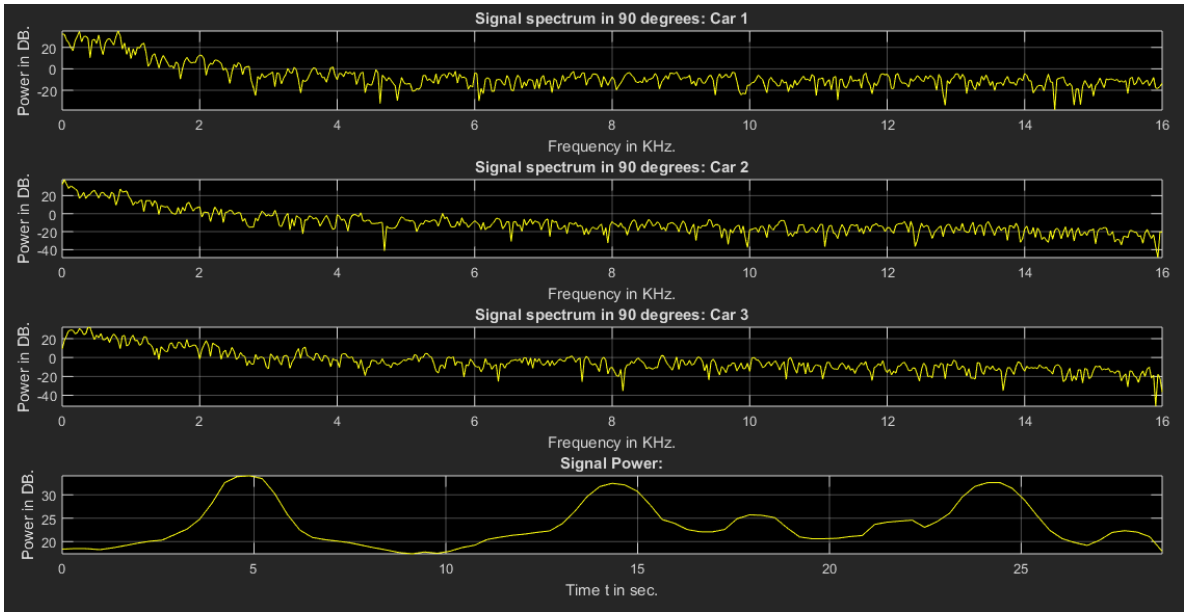


Figure 2.1.9.b: above, in the first three, the power spectrum of each vehicle by 90 ° and below, in the fourth, the energy over time.

- Test 10 – Velocity: 70 Km/h – Orientation: 180° to 0°

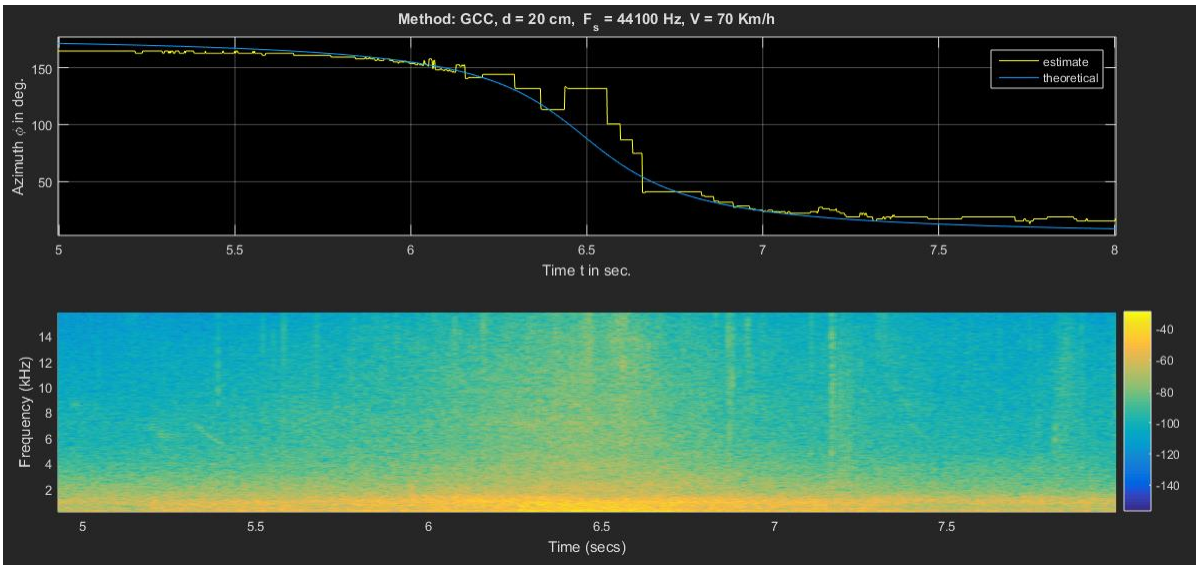


Figure 2.1.10.a: above, comparison between the theoretical azimuth and its estimation, and below, the spectrogram for the full band signal (car 1).

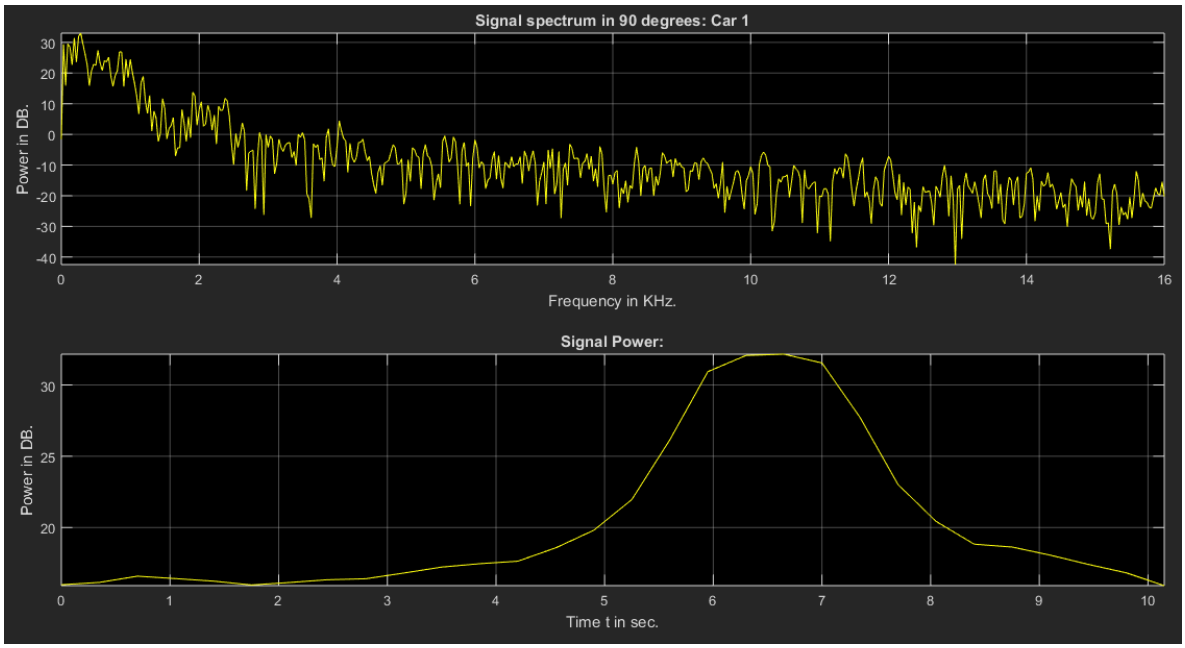
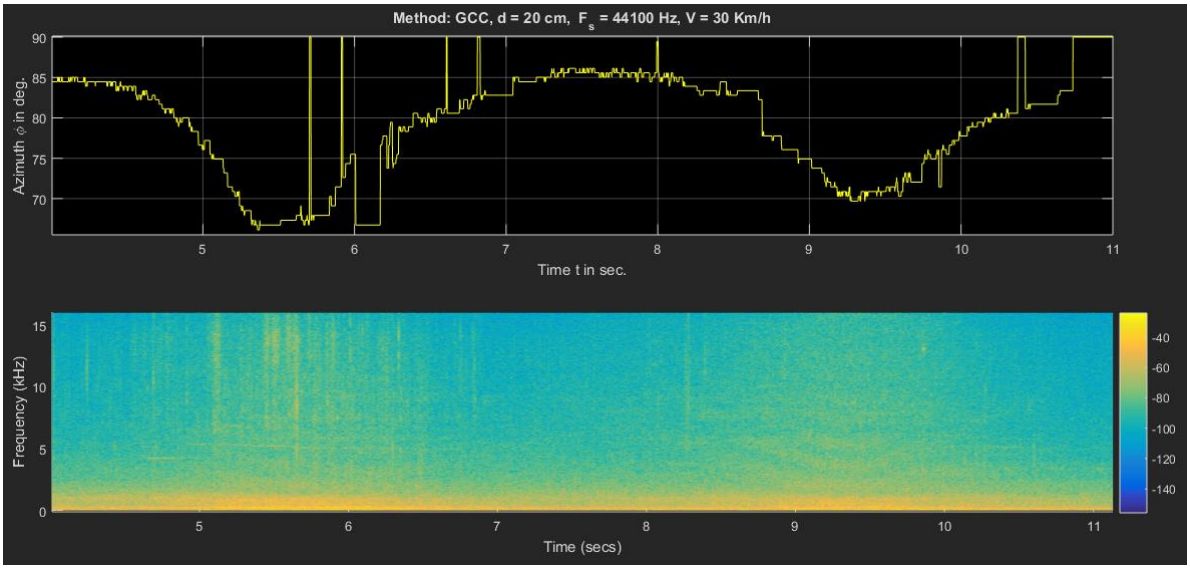
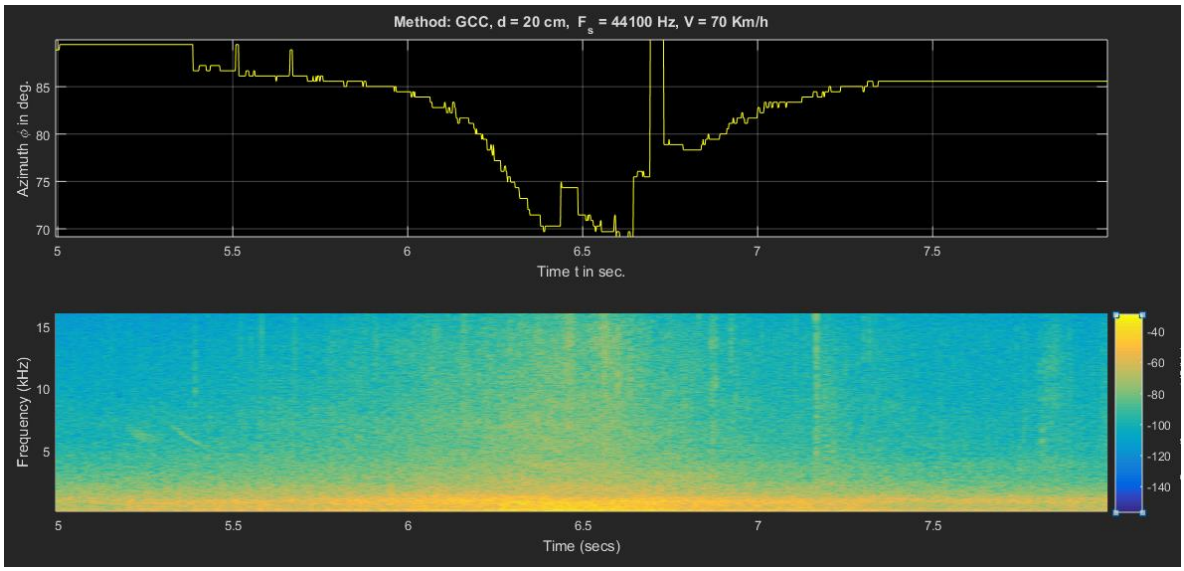


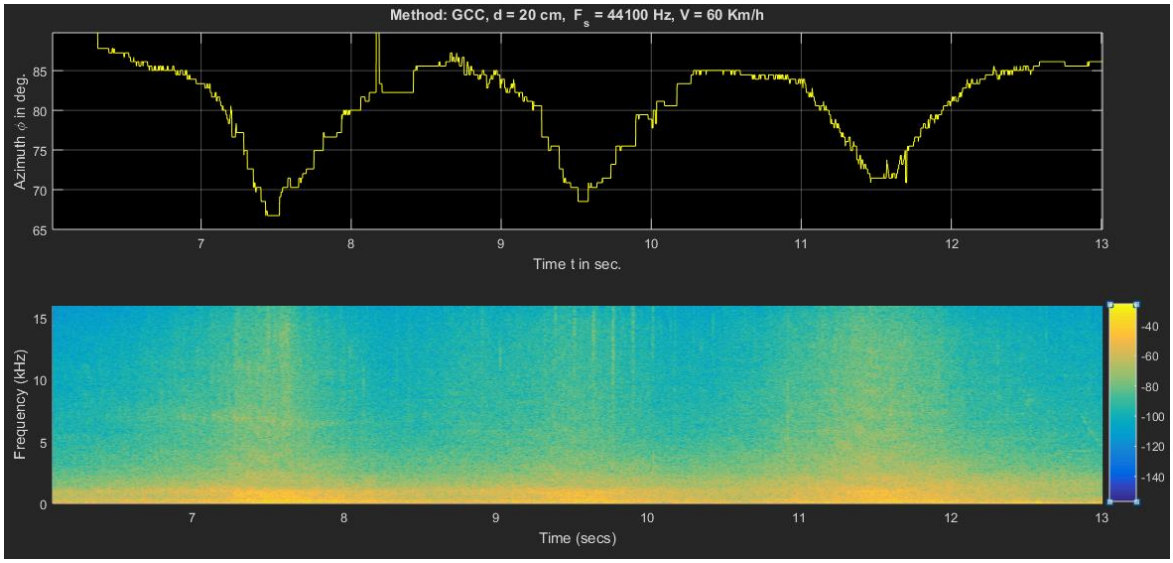
Figure 2.1.10.b: above, in the first, the power spectrum of vehicle by 90 ° and below, in the second, the energy over time.

The table below shows the time instants where energy concentrations occur (90° for DOA), the time interval and distance between cars:

	Instant Time in 90° (s)			Time Delay (s)		Distance Difference (m)	
Test \ Car	1	2	3	1,2	2,3	1,2	2,3
1	5.56	9.31	----	3.75	----	31.25	----
2	7.88	17.23	----	9.35	----	77.92	----
3	4.44	8.38	----	3.94	----	43.78	----
4	5.68	15.28	----	9.59	----	106.57	----
5	5.35	8.48	----	3.13	----	43.41	----
6	6.90	16.00	----	9.10	----	126.37	----
7	6.26	10.03	----	3.76	----	62.73	----
8	7.75	9.75	11.93	2.00	2.18	33.36	36.30
9	5.32	14.33	24.00	9.02	9.67	150.26	161.20
10	6.51	----	----	----	----	----	----




Method: GCC, d = 20 cm, F_s = 44100 Hz, V = 70 Km/h
Azimuth ϕ in deg.
85
80
75
70
5
5.5
6
6.5
7
7.5
Time t in sec.
Frequency (kHz)
15
10
5
-40
-60
-80
-100
-120
-140
Time (secs)


Method: GCC, d = 20 cm, F_s = 44100 Hz, V = 60 Km/h
Azimuth ϕ in deg.
85
80
75
70
65
7
8
9
10
11
12
13
Time t in sec.
Frequency (kHz)
15
10
5
0
-40
-60
-80
-100
-120
-140
Time (secs)