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Description of a Frequency Division Duplex Measurement Trial in the UTRA Frequency Band in Urban Environment

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Abstract

When smart antennas are deployed in Frequency Division Duplex (FDD) applications, it is of great interest to know the correlation between the spatial uplink and downlink radio channels. This document describes the FDD radio channel measurement campaign conducted in the UMTS frequency band in an urban area in the city of Bristol. In the campaign, a wideband vector channel sounder was used to estimate the channels (almost) simultaneously. The channels had a bandwidth of 20 MHz and were centred as in the UTRA FDD bands. The transmitter was equipped with an omni-directional antenna and the receiver with an 8 element wideband dual polarised array. In future work, analysis of these measurement data will increase our knowledge of the correlation between the uplink and downlink channel in UMTS systems, guide us in the creation of a spatio-temporal FDD channel models, and give us a better understanding of the possibilities of robust downlink beamforming algorithms for FDD wireless networks.

FDD Trials

The field trial was made according to the time plan in Table 1 below with 1 day collecting cluttered urban data and sub-urban data. The urban data was collected within the Clifton Area of Bristol, with the receiving array (Rx) mounted stationary on the Physics Building (PB), Tyndall Avenue. The transmitting station (TX) is vehicular mounted and both stationary and drive routes were used while sampling the channel data.

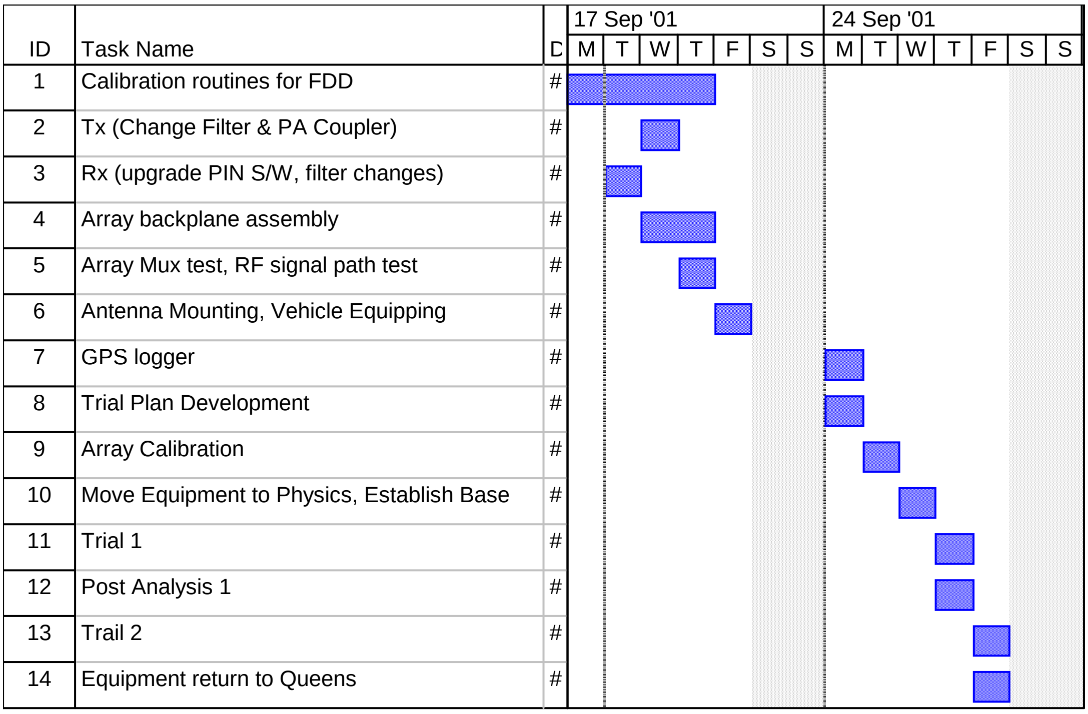

Table 1: Measurement campaign schedule

The Medav RUSK BRI channel sounder was modified to accomplish dual band transmission and reception in the UTRA-FDD uplink and downlink bands. The sounder supports 3 different data acquisition modes. The following text, describes the main features of the acquisition modes. Note that a snap-shot is a vector measurement of 8 Complex Impulse Responses (CIR), each taken from 8 separate antenna element feeds.

Doppler Mode: Multiple Snap-Shots (vector of channel Impulse Responses (CIR) are recorded 'back to back', with the data stored in 2MB of fast RAM. The maximum number of Fast Doppler Blocks (FDB) is either user specified or limited by the storage capability of the hardware. The FDBs are then repetitively written to a slower bank of memory (64MB) at a rate determined by the internal logic of the Medav. Once this memory (64MB) is full, the data recording is complete and the data can then be stored on the hard disc (approx 6GB capacity).

Time Grid Mode: In this mode multiple snap shots can be recorded back-to-back and then written directly to hard disc. Internal processing within the Medav (application of calibration corrections and data formatting) as well as the access time of the hard disc sets the repetition rate. Total record time is limited by available space on the hard drive and the 64MB of RAM is not used in this mode.

Distance Mode: Similar to time grid mode, however an external distance pulse triggers the recording of a FDB. Repetition rate must not exceed the data transfer time and internal processing time within the Medav prior to writing to disc.

Table 2 gives the parameter settings for the Medav, with the ‘Doppler mode’ and the ‘Time Grid mode’ providing suitable combination of operational modes for the trials. Further, it may be viable to consider a sequence period of 3.2µs for in the ‘Urban small cell’ environment, thus decreasing the minimum repetition rate. The shorter sequence period will not be used in the first part of the campaign since the mounted polarisations switches on the antenna array are specified to a maximum switch time of 4µs.

The transmitter power is set to 40 dBm for each frequency band in all measurements. The calibration was made with the TX test signal input in the “cal loop” of the MEDAV RX switch box. The RX array was mounted with 4 degree mechanical downtilt in addition to the 2 degree electrical downtilt, i.e. 6 degree in total. The lower end of the array was 3.6 m above the roof level of the Physics building.

The number of CIR snap-shots must provide enough samples for the DoA algorithms. It has been indicated that 8 vector snap-shots give a good basis for the estimations. Thus 8 snap-shots per frequency and polarisation are necessary for an instantaneous estimation of DoA. However, it is possible to estimate DoA for each polarisation and frequency with a lower number of snap-shots per FDB if samples from consecutive Doppler blocks are used. The different parameter settings ‘A’ to ‘C’ shown in Table 2 were applied for the different trial scenarios and data sets.

Parameter setting	Recording Mode	Sequence period	Snap shots per FDB	Repetition Rate	Recording Period	Duration	Array Configuration
A	Doppler	6.4µs	16	20.48 ms (minimum)	200 FDB	~4s	8 snap shots per Freq (single Pol)
B	Doppler	6.4µs	32	40.96 ms (minimum)	123FDB	~5s	8 snap shots per Freq (dual Pol)
C	Time Grid	6.4µs	32	1751.04ms	1FDB	-	8 snap shots per Freq (dual Pol)

Table 2: Measurement Parameter settings

Scenario 1 - Cluttered Urban Deployment (Rx at Physics Building West)

With the array deployed at the top of the Physics Building, see Figure 1, both static point measurements and drive tests were conducted within the Clifton area of Bristol. The RX array mounted parallell with the building with boresight southwest (approximately 215 degrees) will have the TX locations within the main lobewidth. The data sets taken in scenario 1 are described below and an overview of the locations and routes is shown in the map in Figure 4. An example of a transmitter location is given in Figure 3 where the mobile is stationary at location 2.

Figure 1: View towards Physics Building from Tyndall Avenue

Figure 2: Array sighting on the roof of Physics Building.

Data set 1: 12 static transmitter points (see map given in Figure 4). At each location, the fast Doppler block measurement mode will be used to record one file. First setting 'A' will be used with 8 snap-shots of both frequency bands (total of 16 dual band snap-shots) taking 1.6 ms to complete a FDB. The repetition rate between FDBs in this setting is 20.48 ms and this will be repeated 200 times over a period of 4.1 seconds for each location. The TX antenna is vertically mounted.

Data set 2: The same 12 static transmitter points will be used (see map given in Figure 4). At each location, the fast Doppler block measurement mode will be used to record one file with the parameter setting 'B'. The collection procedure encompasses 8 snap-shots of both polarisations and frequency bands (total of 32 snap-shots) taking 3.2 ms to complete a FDB. The repetition rate between FDBs in this setting is 40.96 ms and this will be repeated 123 times over a period of 5 seconds for each location. The TX antenna is mounted with slant polarisation.

Data set 3: The receiver array at Physics building with boresight south west and drive test (arc): Whiteladies Road, Queens Road, Park Row (see map route A, Figure 4). In this test the time grid measurement mode according to the parameter setting 'C' will be used to take 32 dual polar, dual band snap-shots every 1.75104 seconds throughout the route. A GPS receiver will be used to log position information. The TX antenna is mounted with slant polarisation.

Data set 4: The receiver array at Physics building with drive test (radial): Richmond Hill, Queens Road and University Road (see map route B, Figure 4). In this test the time grid measurement mode according to the parameter setting 'C' will be used to take 32 dual polar, dual band snap-shots every 1.75104 seconds throughout the route. A GPS receiver will be used to log position information. The TX antenna is vertically mounted.

Figure 3: Stationary mobile operation in Clifton Triangle Area, TX location 2.

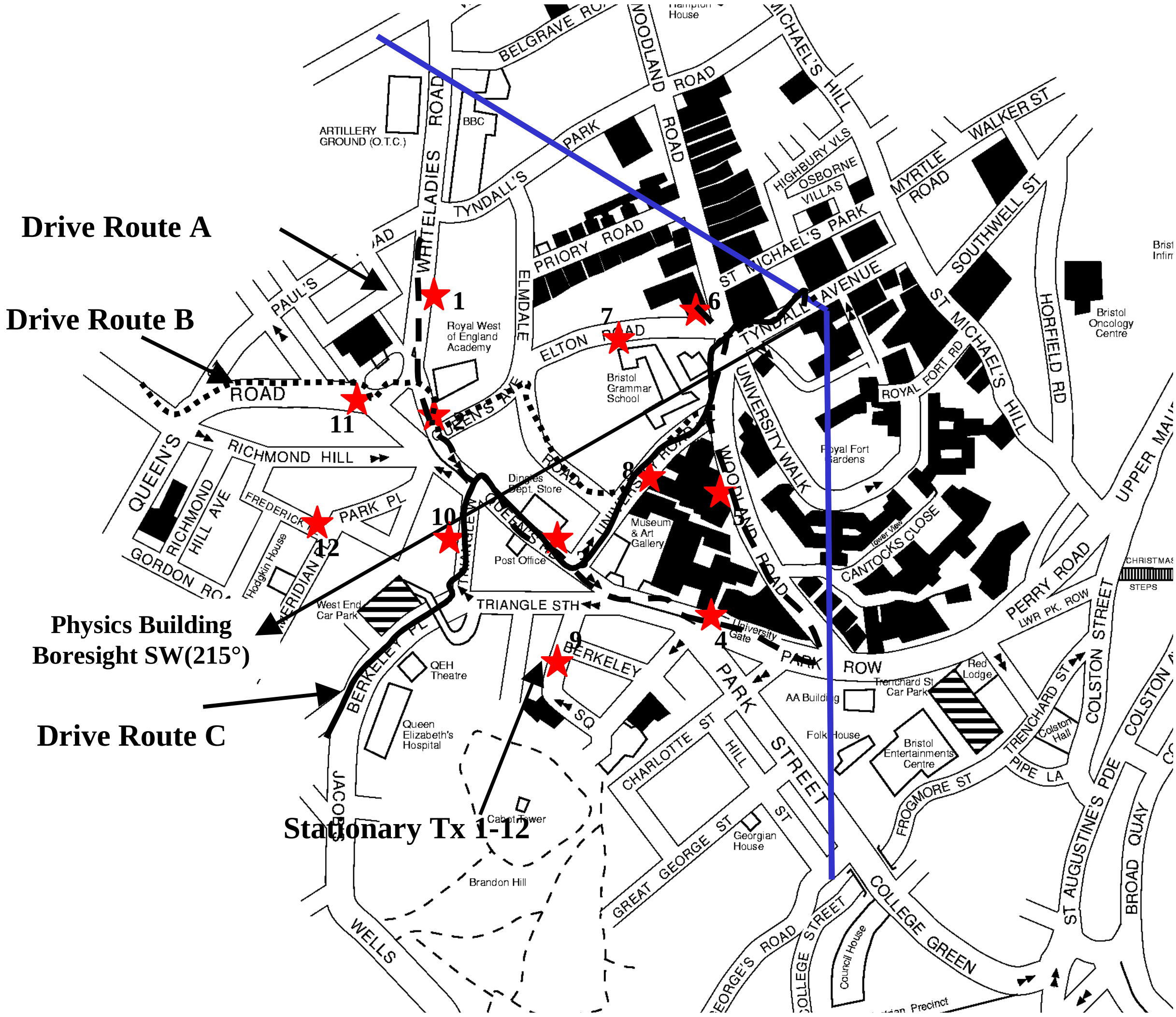

Figure 4: Clifton Urban Area with 12 static points (*) and 3 drive routes (A, B & C).

Scenario 2: Sub-Urban Deployment (Rx at Physics Building North)
The array was also deployed at Physics Building (PB) with boresight approximately towards the water tower, i.e. northwest. Both static point and drive tests were conducted within the Clifton and Redland areas of Bristol covered by the Rx array lobe width, see Figure 5. The data sets 5 to 8 from this trial are described in the following paragraphs.

Data set 5: 12 static transmitter points (see map given in Figure 5). At each location, the fast Doppler block measurement mode will be used to record one file. First setting ‘A’ will be used with 8 snap-shots of both frequency bands (total of 16 dual band snap-shots) taking 1.6 ms to complete a FDB. The repetition rate between FDBs in this setting is 20.48 ms and this will be repeated 200 times over a period of 4.1 seconds for each location.

Data set 6: The same 12 static transmitter points will be used (see map given in Figure 5). At each location, the fast Doppler block measurement mode will be used to record one file with the parameter setting ‘B’. The collection procedure encompasses 8 snap-shots of both polarisations and frequency bands (total of 32 snap-shots) taking 3.2 ms to complete a FDB. The repetition rate between FDBs in this setting is 40.96 ms and this will be repeated 123 times over a period of 5 seconds for each location.

Data set 7: The receiver array at Physics building with boresight south west and drive test (arc): see map route D, Figure 5. In this test the time grid measurement mode according to the parameter setting ‘C’ will be used to take 32 dual polar, dual band snap-shots every 1.75104 seconds throughout the route. A GPS receiver will be used to log position information.

Data set 8: The receiver array at Physics building with drive test (radial): see map route E, Figure 5. In this test the time grid measurement mode according to the parameter setting ‘C’ will be used to take 32 dual polar, dual band snap-shots every 1.75104 seconds throughout the route. A GPS receiver will be used to log position information.

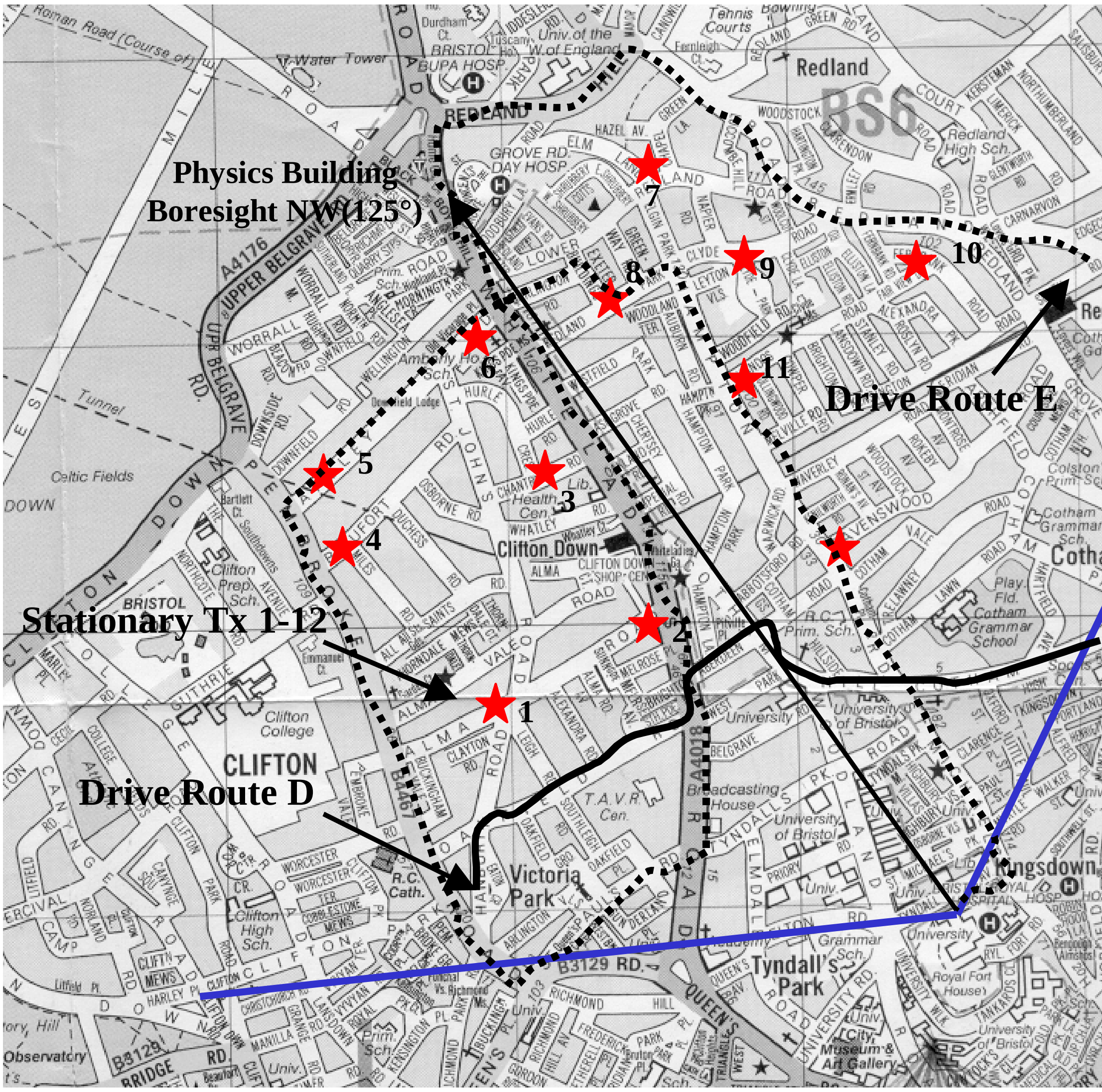

Figure 5: Redland area suburban static points (*) and routes D & E.

Initial Results

In this section, a number of plots generated from the measured data are presented. The aim of the section is not to present an analysis of the measured FDD radio channel, instead the aim is to verify the correctness of the system and the measured channel impulse responses.

The first plot, Figure 6, verifies that the vector channel sounder is switching correctly between frequency bands and polarisations. As was mentioned earlier in this document, the channel sounder was modified to support dual band transmission and dual polarisation on the receiver antenna. The sounder will iterate between these modes, hence the signal in Figure 6 has a period of 4. The figure shows the channel attenuation for one frequency. Snapshot 1 corresponds to positive polarisation in the 2.1 GHz band, snapshot 2 to positive polarisation in the 1.9 GHz band, snapshot 3 to negative polarisation in the 2.1 GHz band and finally snapshot 4 to negative polarisation in the 1.9 GHz band. Snapshot 5 has the same configuration as snapshot 1, it is only taken 40.96 ms later. The iteration order is user configurable. It is also possible to only iterate between the two frequency bands or the two antenna polarisation angles.

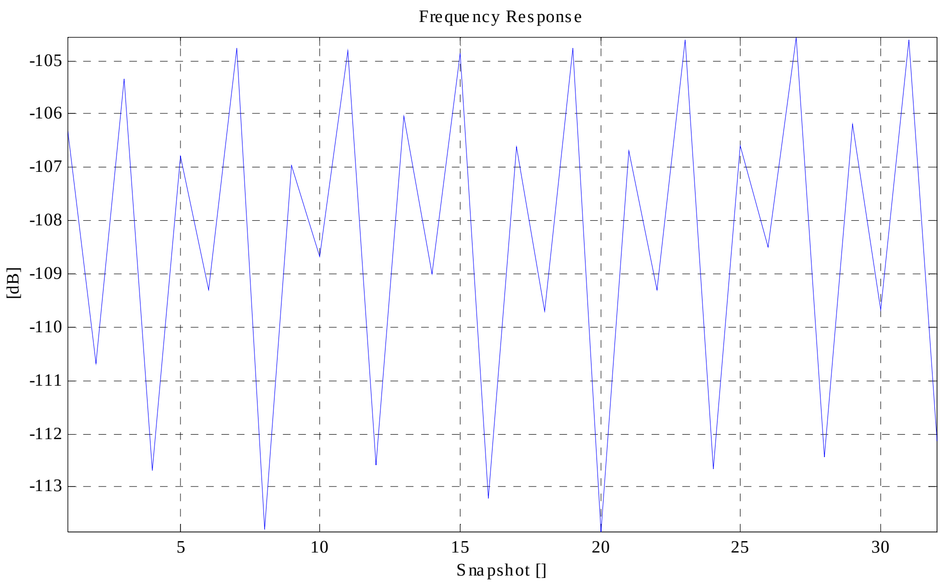

Figure 6: Measurement iteration between FDD channel modes

Figure 7 shows the temporal variation of the frequency response in the 1.9 GHz band. The static transmission point is labelled number 2 in Figure 4, and only one receiver antenna element is used. In the picture, we see a significant change in the channel over the 5 second time span.

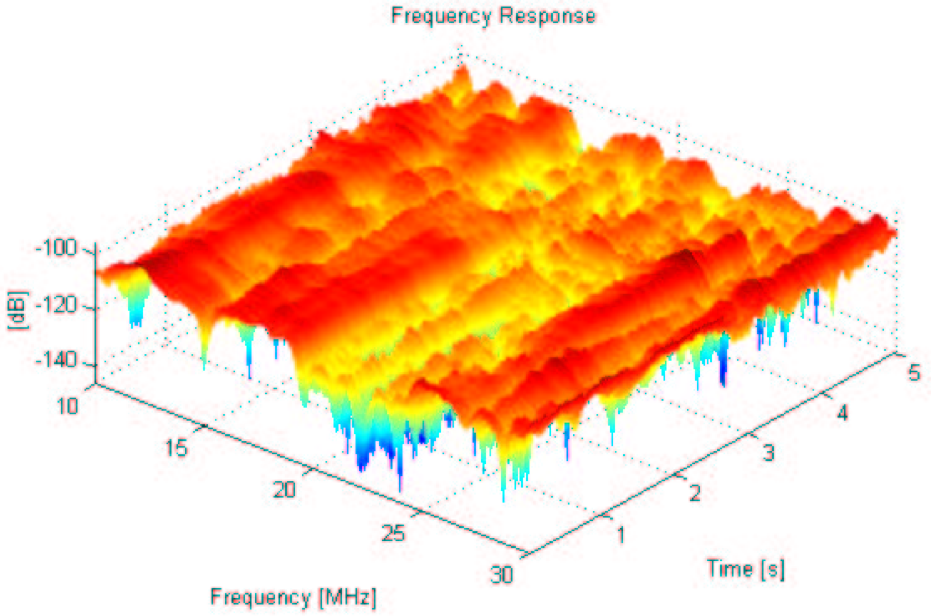

Figure 7: Temporal channel variation

In the next two figures, impulse responses at 1.9 and 2.1 GHz are shown. Like above, transmission point 2 in Figure 4 is used, and the impulse response is derived from one snapshot at one receiver antenna element.

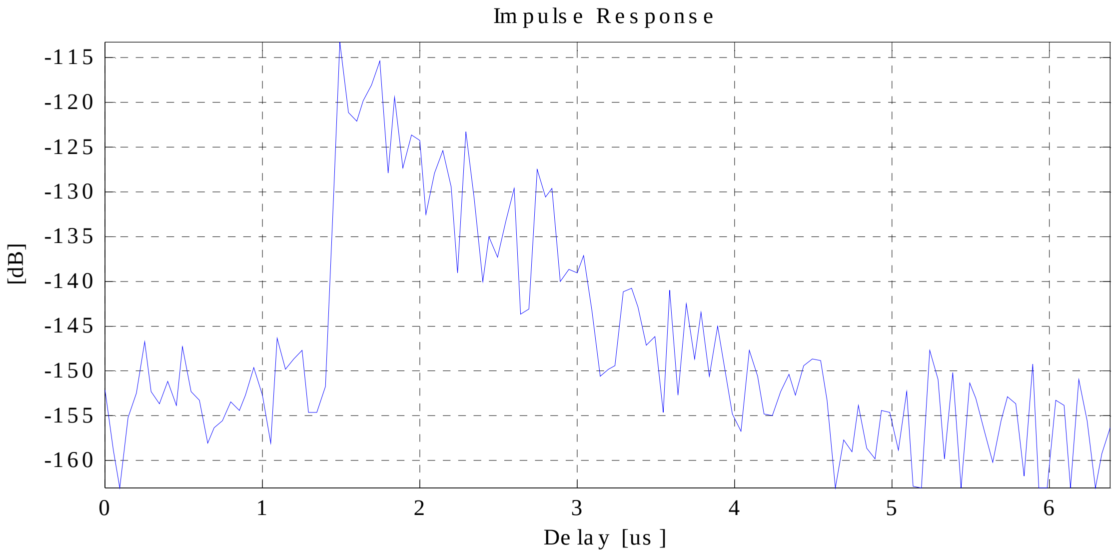

Figure 8: 1.9 GHz impulse response at transmission point 2

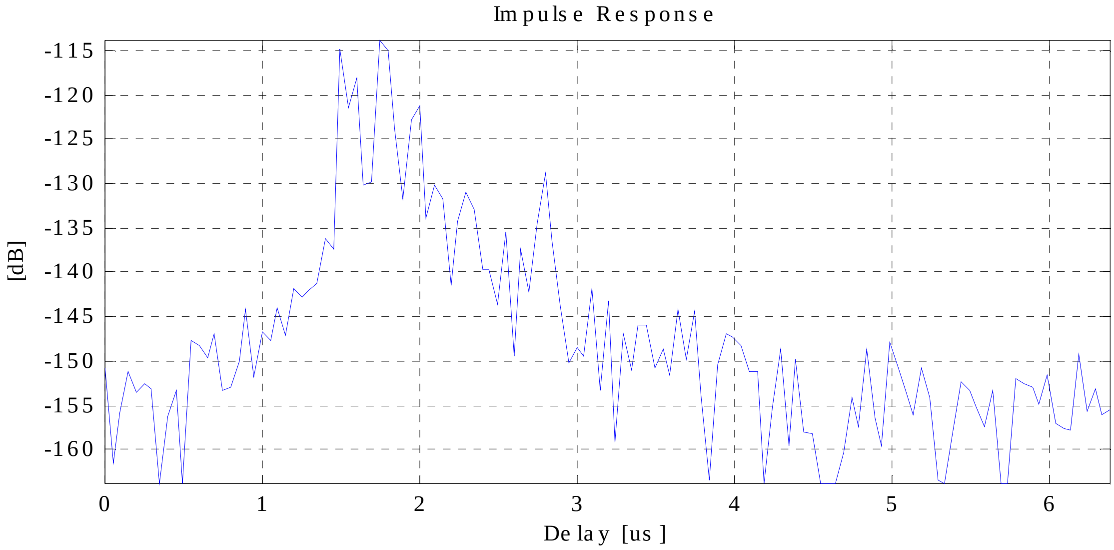

Figure 9: 2.1 GHz impulse response at transmission point 2

In Figure 10, the frequency responses for all antenna elements from one snapshot are shown. Note that severe fading points occur at different frequencies for the different antenna elements.

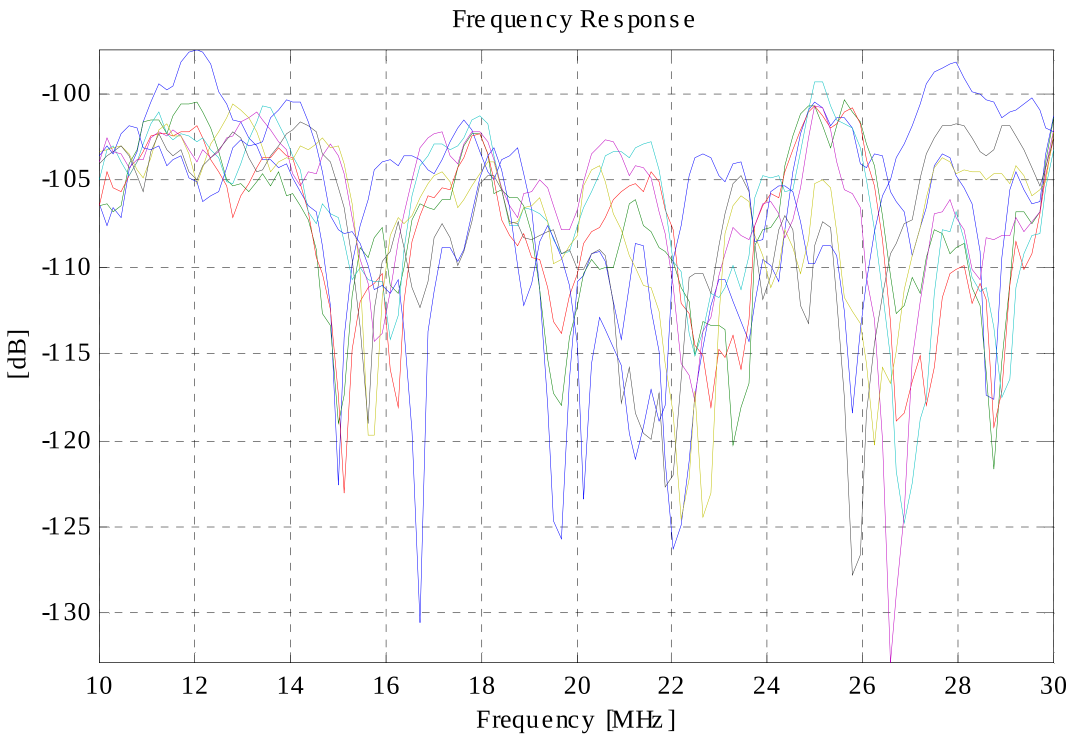

Figure 10: Frequency responses for the 8 antenna elements at one time instance

In addition to measurements performed at static transmission points, several measurements with mobile transmission unit were also conducted. Figure 11 shows the impulse responses as the mobile unit is driving along route A in Figure 4. During the first 250 seconds the distance between the transmitter and the receiver is almost constant. There after the distance is decreasing. It is also highly visible how the channel attenuation varies, as the environment between the transmitter and the receiver is changing.

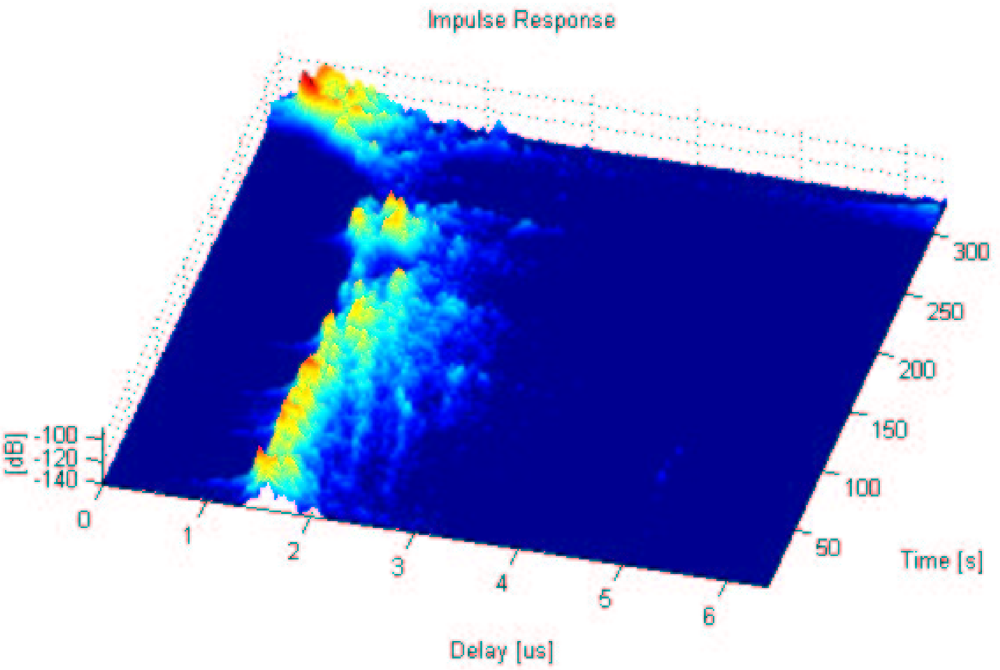

Figure 11: Impulse responses from drive route A in Figure 4.

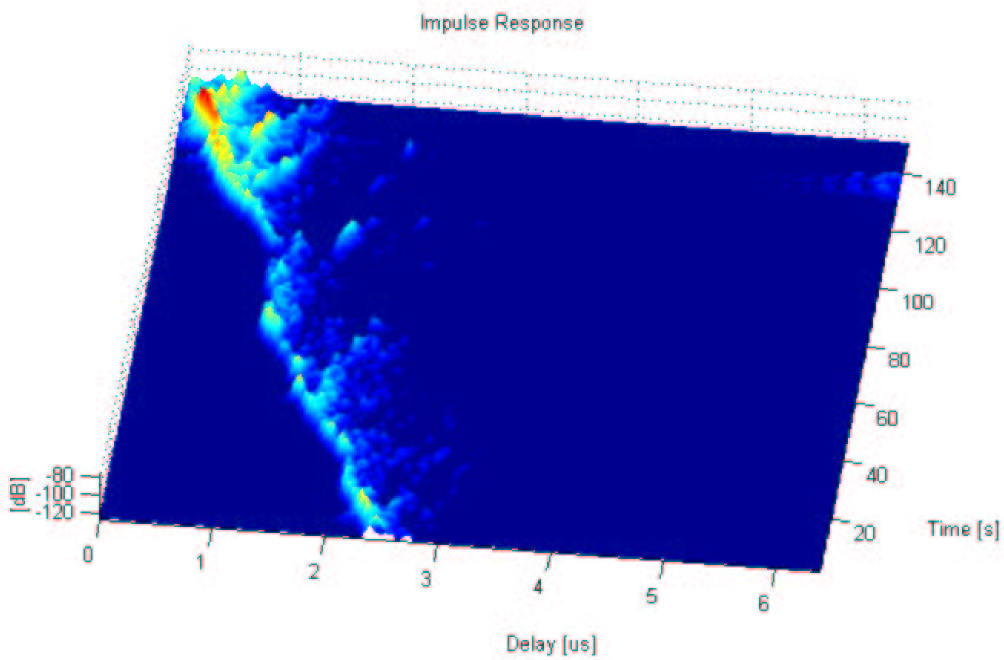

Figure 12: Impulse responses from drive route B in Figure 4.

Finally, two plots are given from the measurements in scenario 2. These measurements are conducted in an sub-urban environment, and several measurement points have a larger distance between the transmitter and receiver than in scenario 1. Remember, the maximum impulse response length is 6.4 µs, corresponding to approximately 1920 m. Figure 13 shows the impulse response when the transmitter is at point 5 in Figure 5. Then in Figure 14, the impulse responses while driving route E in Figure 5 are given. Especially notice how the signal attenuation varies over the route.

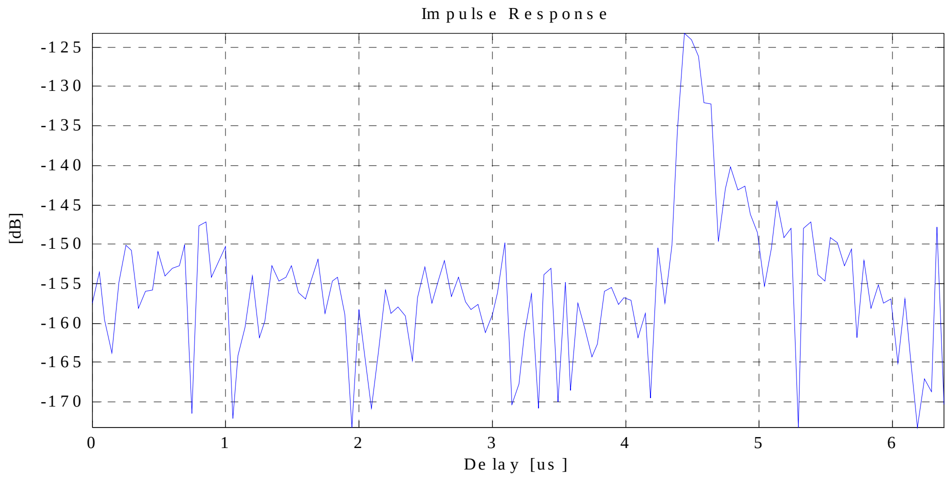

Figure 13: Impulse response for static transmitter at point 5 in Figure 5

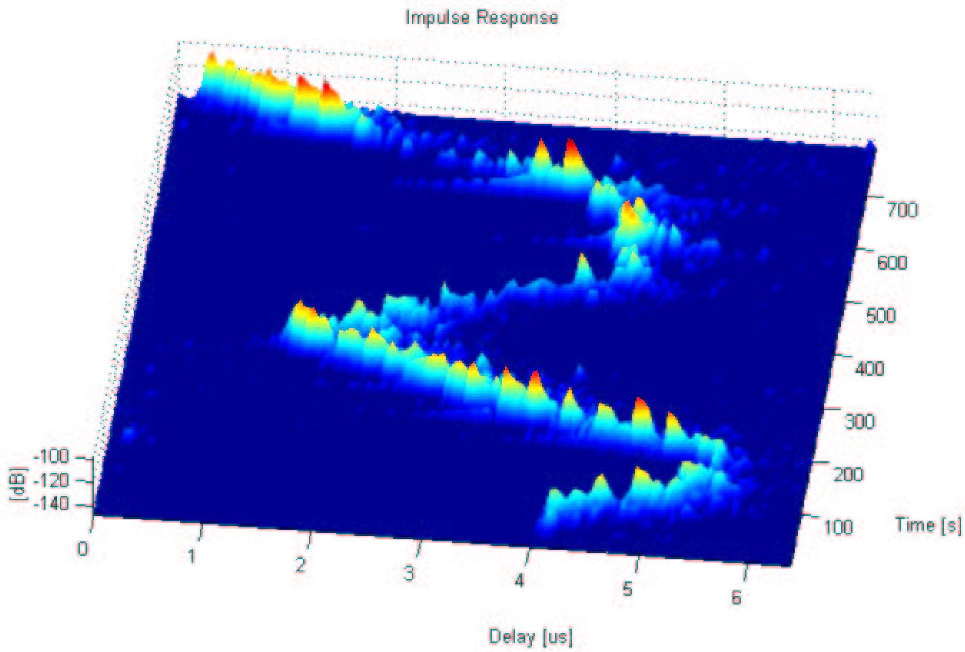

Figure 14: Impulse responses from drive route E in Figure 5