Abstract—This paper presents the first V2I channel sounding campaign with the real-time MaMIMOSA massive radio channel sounder. This equipment has been jointly developed by ULille (FR) and UGhent (BE) for 5G V2X applications. The system is equipped with a massive 64-antenna array for Rx whereas up to 8 individual antennas can be deployed for Rs. The MaMIMOSA hardware and software capabilities allow to freely adapting the sounding parameters to the investigated scenario demonstrating its versatility and flexibility. Radio channels were measured at 5.89 GHz with 80 MHz bandwidth at the ULille campus using with a vehicle speed up to 60 km/h. In addition to this suburban mobility scenario, Obstructed Line-Of-Sight static radio channels were collected for a roadside to parking setup to study the influence of vegetation. Very preliminary Doppler characteristics are reported from the measured radio channels. A deeper analysis will be included in the final paper.

Index Terms—Massive MIMO channel sounding, V2X, propagation, measurements.

I. INTRODUCTION

In our modern world where mobile connectivity has become a necessity for many network users, there is a need for technological advances and computer abilities to provide faster, smarter and safer wireless networks [1]. The upcoming 5G NR (New Radio) being currently defined by 3GPP [2], [3] is expected to reach larger data rates with improved networks efficiency compared to previous legacy standards such as 4G LTE. Moreover, it widens its original radio mobile domain of application by including machines in industrial setups, vehicular communications (vehicle-to-everything or V2X) [4] and smart cities [5], [6]. These use cases encompass three fundamentally different dimensions: enhanced mobile broadband (eMBB), massive machine type communications (mMTC) and ultra-reliable low latency communications (URLLC). Among novel technologies expected to deliver the promised specifications of 5G NR, Massive MIMO [7] and the use of larger bandwidths at millimeter wave (mmW) frequencies are the most widely investigated in the research community. Massive MIMO is an asymptotic extension of multi-user MIMO (MU-MIMO) where the number of transmitting antennas is very large compared to previous MIMO techniques. This enables simultaneously serving many user equipments (UE) within the same frequency-time slot even if they generally are equipped with one antennas one antenna [8], [9]. Early works such as [10], [11] present the fundamental information, theoretical aspects as well as limits of the massive MIMO technology.

Beyond the fact that the main benefits envisioned by massive MIMO must be evaluated (e.g. reduction in latency on the air interface, multiple-layer access simplification or even robustness to undesired or intentional jamming [12]), legacy propagation models used in network planning tools must be revisited accordingly. Furthermore, the wide-sense stationarity (WSS) uncorrelated scattering (US) assumption WSSUS [7] of the channel are not often verified in realistic dynamic environments from the Tx array side. The violation of the WSSUS assumptions which can happen in practice in vehicular scenarios [13] avoid a simplified statistical description of channels. It follows real-time massive MIMO systems must be used to assess the WSSUS assumptions and is a requisite to grasp the time-varying spatial characteristics of the radio channel. This approach can be rather cost-expensive due to the architecture complexity [14] resulting in RF impairments or synchronization issues between the massive array and the UEs.

To this end, a real-time 64 x 16 massive MIMO radio channel sounder operating between 2 and 12 GHz with 80 MHz bandwidth has been jointly developed by the University of Lille (France) and Ghent (Belgium) for 5G mobility scenarios such as V2X communications [15]. The architecture relies on the physical and reconfigurable software radio channel sounder MIMOSA [16]. MaMIMOSA has been designed to fulfill all the constraints identified in time-varying massive MIMO channels such as high Doppler resolution with a large Doppler span, spatial antenna selection, compactness, energy consumption, etc. The sounding parameters of the developed massive system can be freely selected depending on the studied environment resulting in the measured massive MIMO radio channel without the need for additional tedious post-processing. The MaMIMOSA antenna array is a 10 x 10 vertical planar antenna array built by the University of Ghent. 64 elements of the array are SMA-connected to the Tx unit using coaxial cables whereas the 36 remaining antennas at the
In this work, MaMIMOSA was setup to perform up to 64 x 8 massive radio channel measurements at 5.89 GHz with 80 MHz bandwidth for V2I communications. In a first set of measurements, 64 x 1 time-varying radio channels were assessed on the scientific campus of the University of Lille with a vehicle speed up to 60 km/h. In a second set, static Obstructed Line-Of-Sight (OLOS) 64 x 8 radio channels were measured between the transmitter located on the roadside and receiver on an adjacent parking lot to study the influence of vegetation. Since the campaign is very recent, only an early analysis of the Doppler characteristics were evaluated from the measured channels. A deeper analysis of the fading and Doppler characteristics will be presented in the final paper. Nonetheless, The campaign already highlights the potential of MaMIMOSA to faithfully grasp the main characteristics of massive radio channels which can be subsequently used for developing realistic radio channel models.

II. MAIMIMOSA FRAME STRUCTURE

A. Streaming mode for time-varying scenarios

When a scenario with large mobility is considered like for v2X communications, the MaMIMOSA streaming mode is selected and is associated the frame structure illustrated in Fig. 1(a). Each frame consists in one 51.2 µs preamble subsequently followed by 128 blocks of 8 121.92 µs OFDM symbols including the cyclic prefix. The total frame duration to measure a single 64 x 16 massive MIMO matrix is ~1 ms and ~125 ms. Hence, the maximum Doppler span is ± 512 Hz (93 km/h maximum speed) with 8 Hz Doppler resolution. The preamble provides the time synchronization of the frame required to decode the OFDM symbols. Each OFDM symbol corresponds to an 8-antenna subarray out of 64. The time duration between consecutive frames was manually set to 500 ms. Since the maximum power per RF chain is 30 dBm, during the whole measurement campaign knowing that the maximum power per RF chain is 30 dBm. The emitted power per RF chain was set to 0 dBm.

B. Streamshot mode for static scenarios

When the time-variation of the radio channel is not the purpose of the measurement or simply because the radio channel is supposed to be static in nature, the streamshot mode of MaMIMOSA can be selected and is associated the frame structure illustrated in Fig. 1(b). Each frame consists in one 51.2 µs preamble subsequently followed by a single block of 8 121.92 µs OFDM symbols including the cyclic prefix. The total frame duration to measure a single 64 x 16 massive MIMO matrix is ~1 ms. The time duration between consecutive frames was also manually set to 500 ms. Since time-synchronization is performed to measure a single massive radio channel, the Doppler information is lost. However, this mode relaxes the streaming and processing constraints within the FPGA to the hard drive in contrast to the streaming mode.

III. MEASUREMENT CAMPAIGN DESCRIPTION

The massive 64-antenna array was placed on a tripod at same location on the sidewalk during the whole measurement campaign. The emitted power per RF chain was set to 0 dBm during the whole measurement campaign knowing that the maximum power per RF chain is 30 dBm.

A. V2I scenarios

Figure. 2 depicts a schematic top view of the V2I measurement campaign at the ULille campus. Tx was placed such that its main radiating lobe was parallel to the main boulevard. The single receiver antenna Rx was placed on a van rooftop and is the same as the elementary antenna of the array. The van performed a drive test along the boulevard with maximum speed of 60 km/h toward Tx. The massive radio channel was measured during 118 frames with the streaming mode for a total recording time of ~54 seconds. Figure. 3 presents a picture from the rear side of the Tx array with the van completing its drive test.

B. Static scenarios

In addition, Figure. 4 depicts a picture of the 4 OLOS measurement scenarios between the Tx array (located at same
place than for the V2I scenario) and 8-antenna Rx array. Tx array was facing the building. The measurement recently took place at the end of the summer such that the foliage of the trees separating the sidewalk and parking was dense. The massive radio channel was measured during 236 frames with the *streamshot* mode.

**IV. PRELIMINARY DOPPLER RESULTS**

Figure. 5 presents the Doppler shift measured for the V2I scenario averaged for Tx antenna 1 as a function of the number of frames (Tx - Rx distance). The associated vehicle speed computed as the maximum in the Doppler spectrum for each frame is in good agreement with the speed maintained during the measurement. A spike can be observed and is associated with the first speed bump labeled D2 along the main boulevard as seen in Fig. 2.

In addition, Fig. 6 presents the estimated Delay-Doppler profile as a function of Tx - Rx distance for frame #10 and Tx antenna 1 as an example. The spectrum indicates the presence of several multipath components with similar Doppler shift values as the principal Doppler shift due to the van.

**V. CONCLUSION**

In this contribution, the real-time 64 x 16 massive MIMO sounder called MaMIMOSA based on space-frequency division multiplexing and antenna subarray switching has been used for a measurement campaign at 5.89 GHz with 80 MHz bandwidth on the University of Lille Campus. using different Massive transmitter-receiver configurations with vehicle speed up to 60 km/h. In addition, the influence of vegetation was investigated thanks to the measurement of OLOS static
radio channels from the roadside to a parking lot. The very preliminary Doppler characteristics were evaluated from the measured radio channels and are shown to agree well with the campaign setup. A deeper analysis if the radio channel fading and Doppler characteristics for both time-varying and OLOS scenarios will be presented in the final paper.

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REFERENCES


