4× MIMO prototyping system

In this short paper, a MIMO prototyping system is introduced to verify the effectiveness and feasibility of the any proposed algorithms in practical wireless MIMO communications. The prototyping implements important features of an orthogonal frequency division multiplexing (OFDM) physical layer, with third generation partnership project (3GPP) long-term evolution (LTE) time-division duplex (TDD)-like specifications.

I. Hardware Description

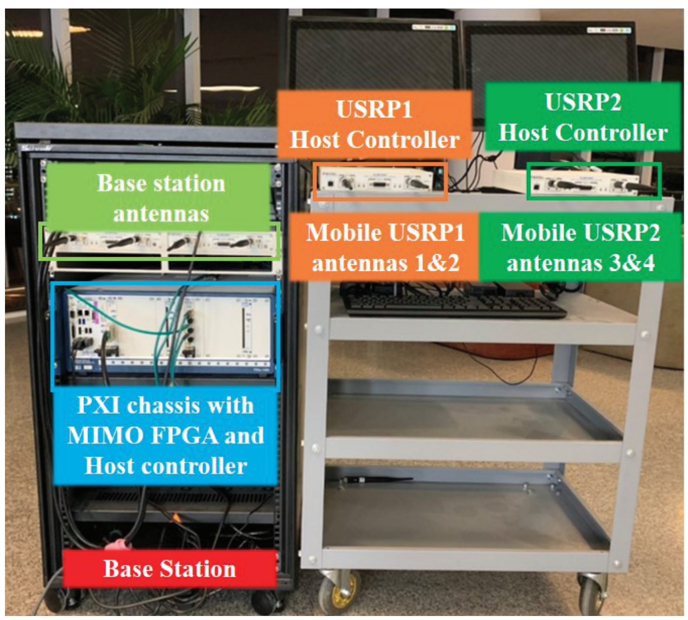


Fig. 1. System hardware equipment overview.

To measure the channel characteristics of the MIMO channels, 4 universal software radio peripherals (USRP) are used to form a 4×4 MIMO prototyping system, which operating at 3.5GHz microwave band. Each USRP comprises two omni-directional antennas, two radio chains, and the respective ADC/DAC modules. It implements OFDM functionality such as (I)FFT as well as digital front end functionality such as re-sampling on an FPGA. We use 4 antenna elements (2 USRPs) as the RX, thereby emulating a MIMO BS (Fig. 1). Data arriving from the 4 antennas of BS is forward to the MIMO processors, which are implemented on a independent FPGA device in the PXI-Chassis. The FPGA device comprises MIMO processing operations such as precoding and equalization, as well as channel estimation in frequency domain. Two USRPs equipped with 4 antennas are used as transmitters (Fig. 1), each USRP is connected with a controller computer. Note that a single USRP supports two antennas. It also supports the signal processing for two single antenna mobile stations which operate independently. Here we utilize 4 antennas to represent four independent users.

II. Physical Layer Description

The prototyping system implements parts of an LTE-like physical layer in TDD mode. Uplink and downlink are based on OFDM using 20 MHz channel bandwidth.

A. Radio Frame Format

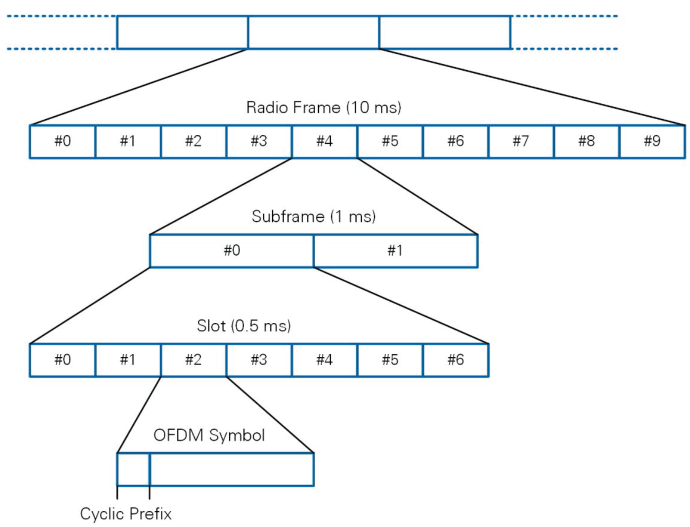


Fig. 2. Radio Frame Structure.

This prototyping system uses a standard 3GPP LTE radio frame structure as shown in Figure 2. Radio frames of 10 ms duration are sub-divided into 10 subframes of 1 ms duration each. Each subframe contains two slots of 0.5 ms duration. A slot is further split into 7 OFDM symbols.

B. Resource Block

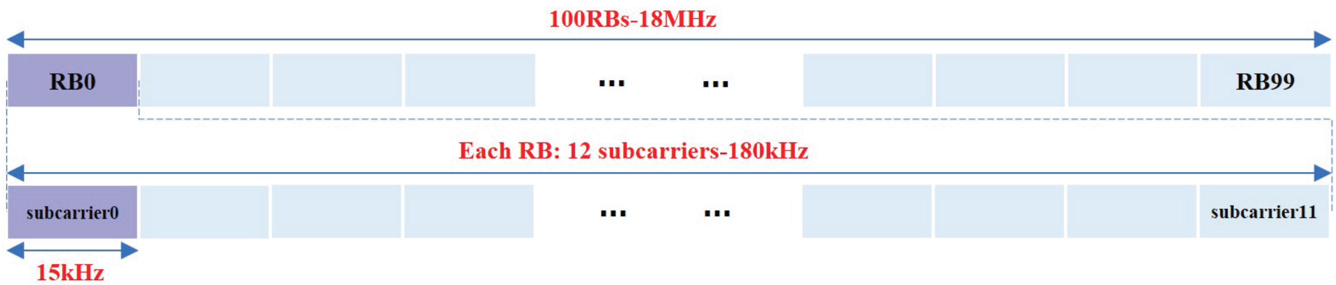


Fig. 3. Physical Resource Block Illustration.

As shown in Fig 2, the OFDM system utilize a total of 1200 subcarriers with the bandwidth 18MHz, of which are divided into 100 resource blocks (RBs), i.e., each RB contains 12 OFDM subcarriers, and the bandwidth of each subcarrier is 15KHz.

C. OFDM Symbols Description

Each OFDM symbol carries a single signal type as listed below:

- *Primary Synchronization Signal (PSS):* The PSS is compliant with the LTE standard [1]. The PSS sequence generation is implemented statically for Cell-ID 0.
- *Pilot Signals:* The same length-1200 quadrature phase-shift keying (QPSK) sequence is used to derive uplink and downlink pilots. Pilot sequences corresponding to different mobile stations are transmitted in a frequency orthogonal fashion, e.g., a pilot corresponding to mobile station 1 occupies the first subcarrier in each RB. A pilot corresponding to mobile station 2 occupies the second subcarrier in each RB and so forth. Note that in our 4×4 MIMO-OFDM prototyping system, users occupy 4 subcarriers of total 12 subcarriers in each RB. To estimated the MIMO channel, a radio frame must contain at least one uplink pilot symbol. A new MIMO channel estimate is obtained whenever a pilot symbol is received. The data symbol which follows this pilot symbol is equalized using this new channel estimate already. The channel estimate is held constant until the next pilot symbol is received.

- *Physical Downlink Shared Channel (PDSCH):* Downlink payload data is transmitted over the PDSCH without forward error correction coding. PDSCH processing comprises:
  - Scrambling using a polynomial in accordance to the LTE specifications [1].
  - Modulation in accordance to the LTE specifications [1].
- *Physical Uplink Shared Channel (PUSCH):* The PUSCH is symmetric to the PDSCH..
- *Guard:* One OFDM symbol including cyclic prefix (CP) where nothing is transmitted in uplink or downlink direction.

Finally, table I summarizes the system main parameters.

Parameter	Value
Center Frequency [GHz]	3.5
Channel bandwidth [MHz]	20
Fast Fourier transform (FT) Size	2048
Number of used subcarriers	1200
Number of RBs	100
OFDM symbol duration [us]	66.67
OFDM symbols per slot	7
Slot duration [ms]	0.5

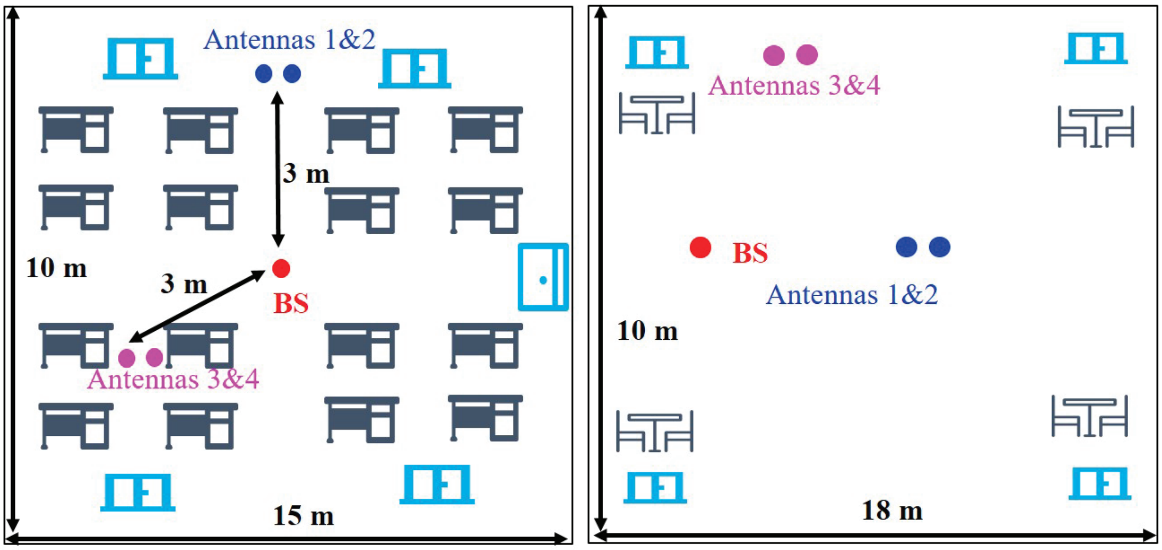
TABLE I

MIMO OFDM NUMEROLOGY

III. MIMO CHANNEL MEASUREMENT

In the OTA test, we conduct two scenarios of indoor channel measurements, indoor-office, and indoor-hall. Each scenario including the static and dynamic MIMO channels.

The indoor-office measurements are conducted at a typical office room, where a wealth of scatterers and reflectors exists. As shown in Fig. 4(a), the base station is fixed in the central of the office room to collect uplink channel data, and four mobile antennas are separated into two different places. The first case is a line-of-sight (LOS) case (marked in blue), where users are positioned close to the base station with LOS paths available. The second case is non-line-of-sight



(a) Indoor-office measurement scenario (b) Indoor-office measurement scenario

Fig. 4. Illustration of two different measurement: the sky blue edges indicate the door and windows.

(NLOS)case, where mobile antennas are surrounding the library with the LOS path blocked by desks and tables (marked in pink red). The sky blue edges indicate glass doors and windows. We altered two setup configurations for the indoor-office measurements, including mobile antennas stay still and keep moving at a uniform speed of $1m/s$ inner the office room (horizontal plane only).

For the indoor-hall measurements shown in Fig. 4(b), we also selected the base station as receiver which fixed in the left central of a open indoor-hall. Four mobile antennas remain stationary or slow-moving at a uniform speed of $1m/s$ in the front semicircle of the base station, which have LOS paths available to the base station.

REFERENCES

[1] 3GPP, ”TS36.211: Evolved Universal Terrestrial Radio Access (E-UTRA); Physical Channels and Modulation (Release 10), V10.7.0,” 2013-02.