Radio channel propagation measurements using a multiband agile chirp sounder

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Abstract

A newly developed multi-band FMCW channel sounder at Durham University was used to perform measurements in the ISM bands in three test beds and on-body measurements in the 60 GHz band. The sounder uses an agile frequency synthesiser to sweep across its bandwidth which enables real time measurements in comparison to the Vector Network Analyser. In this paper we present the estimated rms delay spread for the on body configuration and in the test bed environments. We also present estimated path loss coefficients in an office environment and a semi-shielded environment.

1.Introduction

Recently, multi-tier multi-frequency radio networks have been proposed to provide the required high data rates for the transmission of video signals and internet access [1]. This has stimulated the need for multi-band radio channel measurements such as a combination of the mm band e.g. the 60 GHz where large bandwidths are available for short range communication and current cellular frequency bands such as in the 2 GHz band, and the recently allocated digital dividend in the 800 MHz band for larger cell coverage. To enable multi-frequency measurements a compact wideband frequency channel sounder was designed and implemented. The sounder has five frequency bands: dc-1 GHz which includes the TV white space, the 2.2-2.95 GHz band which includes the LTE and ISM 1 band, the 4.4-5.9 GHz band which covers the C band and the ISM2 band, 14.5-16 GHz and the mm band 58-64 GHz. The sounder uses a frequency agile digital synthesiser which can sweep across any of these bandwidths in 204.8 μs which permits single and multiple antenna measurements. The 60 GHz band is attractive as there are large bandwidths and due to oxygen absorption provides covert communication for the dismounted soldier. Hence this band can be suitable for image transmission over short distances with the antennas mounted on body.

Under the Open Call 1 of CREW (Cognitive Radio Experimental World), measurements were performed in the ISM1 band in three test beds: the air cabin in EADS, the office environment at the Technical University of Berlin (TUB) and the semi-shielded environment in iMinds. The measurements were performed with 550 MHz bandwidth with waveform repetition frequency (WRF) equal to ~1.1 kHz in the ISM 1 band (2.2-2.75 GHz). Where possible the data were acquired at the positions of the nodes in the test beds. Thus for example in the measurements at TUB, the antennas were placed in close proximity to the nodes which are all mounted on the ceiling. Similarly in the test bed at iMinds, the antennas were placed in the locations of the nodes which are at about 1.5 m above ground. The sounder was also used for on body measurements in the 60 GHz band with 4.4 GHz bandwidth and ~1.1 kHz WRF. The measurements included on body antennas for transmission and reception and on body to off body.

In this paper we present a brief overview of the sounder with performance results. This is followed by the results of rms delay spread in the three test bed environments and the estimated path loss in the TUB office environment and in the iMinds test bed. In addition, we present results of rms delay spread in the 60 GHz band for on body networks.

2. Multi-band sounder

The sounder is based on the digital chirp technique using a direct digital synthesiser that can be clocked at 2.15 GHz thus enabling the generation of baseband signals up to ~1 GHz. For measurements in the first ISM 1 band, the output of the digital synthesiser is low pass filtered to remove the higher frequency components and is then up converted using a local oscillator (LO) at 3.2 GHz. The output of the mixer is filtered with a band pass filter (BPF) with 750 MHz bandwidth to pick up the lower sideband. For higher frequency measurements the output is multiplied by two to generate a signal with a maximum bandwidth of 1.5 GHz in the 4.4-5.95 GHz band and up converted to 14.5-16 GHz using a LO at 20.45 GHz and a BPF. This is then multiplied by four to generate a maximum bandwidth of 6 GHz in the 60 GHz band. All the frequency bands up to 14.5-16 GHz are currently based on single input single output architecture with the possible use of a fast RF switch for multiple antenna applications. The 60 GHz band has two parallel transmitters which are switched on and off sequentially every sweep and two parallel receivers for simultaneous acquisition.

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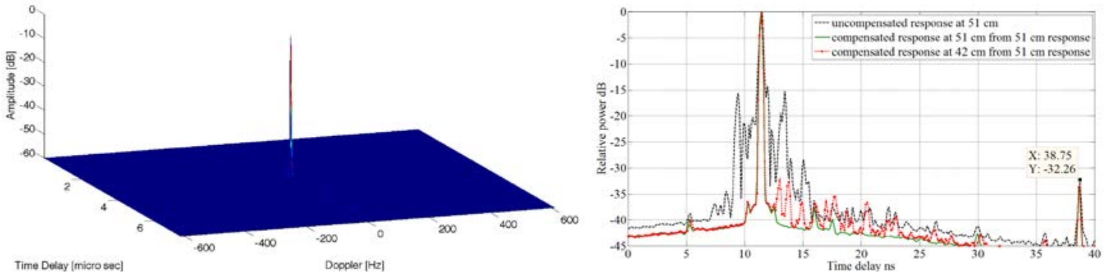
The receiver of the sounder is based on the heterodyne detector [2] where a replica of the transmitted chirp is used as the LO. Following the RF stage of amplification and filtering the received signal is mixed with the local replica to generate a low pass signal which is filtered, amplified and acquired using a two channel analogue to digital converter. Each of the transmitter and the receiver have a high stability rubidium standard with distribution boards to lock all the LO's and to generate the clock for the data acquisition card.

The sounder's performance was verified from back to back tests. Fig. 1.a displays the performance of the sounder in the ISM 1 band in time delay and in Doppler shift and Fig. 1.b shows the time delay resolution in the 60 GHz band. Due to the high sidebands of the compressed signal (~16 dB below the peak), a LOS measurement at 51 cm separation between the transmitter and receiver antennas was used to compensate for the non-ideal response which as can be seen from the figure gives a dynamic range in excess of 30 dB.



(a) (b)

Fig. 1 Delay-Doppler performance of the sounder

3. Measurements in the 60 GHz band for On body applications

Although the sounder has a 2 by 2 MIMO capability only one transmitter and one receiver were used in the measurements reported in this paper. Two quarter-wavelength monopoles with circular 25-mm-diameter ground planes were used for the on-body measurements. Fourteen on body measurements were performed with the test subject performing different movements with the placement of the antennas as in Fig. 2(a) and 2(b). Further twelve measurements with a 20-dBi rectangular horn antenna fixed off body on a trolley and one monopole on body on the belt, as shown in Figure 2(a) were performed with separation up to 6 m.

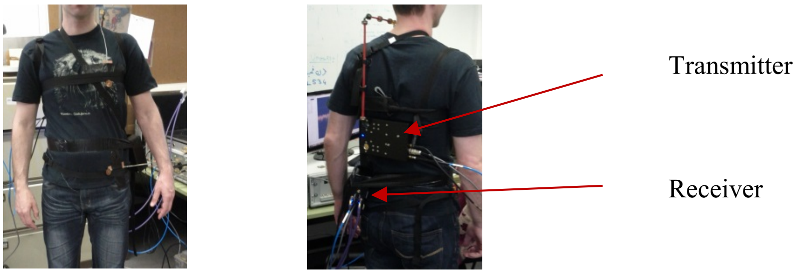


Figure 2 Placement of the antennas for the on-body measurements

Figure 3.a displays six power delay profiles for 1-6 m separation for on-body measurements while Fig. 3.b displays on-body measurements. The on-body measurements show a consistent line of sight component whereas the off-body measurements exhibit several components with comparable strength.

(a) (b)

Fig. 3 Power delay profiles for (a) off-body measurements, (b) on body measurements

The data were analysed for rms delay spread and the results are displayed in Fig. 4. The 90% value of rms delay spread is 2.45 ns for the on-body in contrast to 4 ns for the off body measurements which indicate that a higher data rate can be achieved due to the LOS component. While these measurements show the trend in the rms delay spread, more measurements are needed for different other scenarios prior to drawing final conclusions.

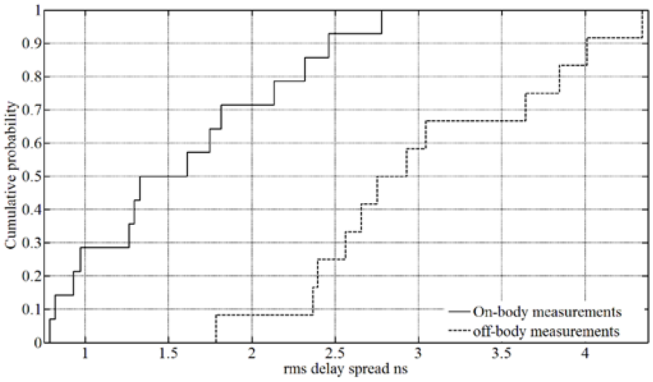


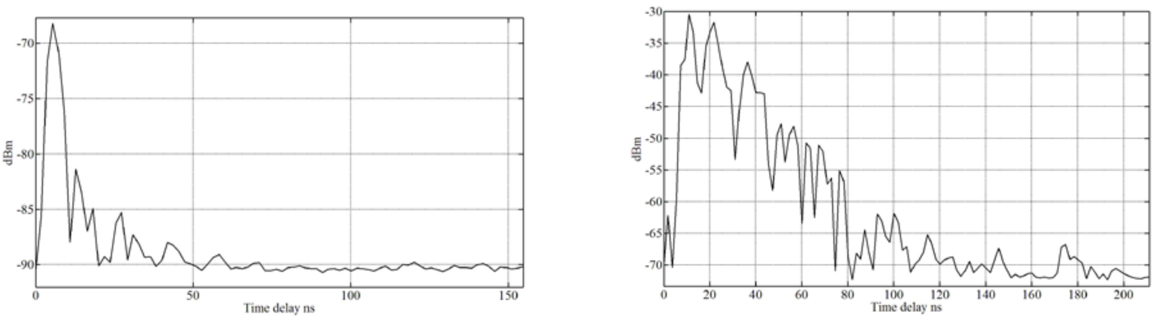
Fig. 4 Cumulative probability distribution function for on-body and off-body measurements

4. Measurements in the ISM1 band in CREW test beds

Radio channel measurements were performed in three of the CREW test beds: the air cabin at EADS, the test bed at TUB which represents an office environment and the semi-shielded environment in iMinds. The measurements in the air cabin were taken with the transmit and receive antennas being placed at different heights to emulate access point to access point, ceiling to lap top, ceiling to isle seat and ceiling to trolley. At TUB the transmit antenna was placed either at 1.5 m or at the ceiling height and the receive antenna was either mounted on a trolley at 1.5 m or at the ceiling level at 2.6 m. Measurements were performed both in corridors and in offices. In iMinds both the transmitter and receiver antennas were mounted at similar height to the nodes at about 1.5 m. Table 1 below summarises the results of the rms delay spread in the different environments. Comparing the results of the office environment at 2.6 m and 1.5 m, the rms delay spread for the lower antenna height is generally higher when the antenna is placed at 1.5 m. This is due to the higher attenuation experienced at the ceiling level due to the construction of the building which had beams below the ceiling. Fig. 5 shows an example of the PDP for both the ceiling height and the desk top level measurements where the vertical axis represents the actual received power in dBm. Overall, the highest rms delay spread is experienced in the semi-shielded environment where a large number of metallic pipes are present leading to a large number of reflections as illustrated in Fig. 6.

Table 1 Summary of rms delay spread obtained in the test bed environments

	Transmitter in office with antennas at ceiling height ~ at 2.6 m	Transmitter in corridor with antennas at 1.5 m	Transmitter in office with antennas at 1.5 m	Air cabin	Semi shielded environment industrial indoor environment
Median value	11 ns	18.53 ns	13.74 ns	11.89 ns	69.2 ns
90% value	12.5 ns	25.16 ns	20.15 ns	14.47 ns	87.2 ns
10% value	8 ns	8.49 ns	10.74 ns	7.98 ns	51.5 ns



(a) (b)

Fig. 5 Power delay profile in the office environment (a) antenna at ceiling height, (b) antenna at 1.5 m

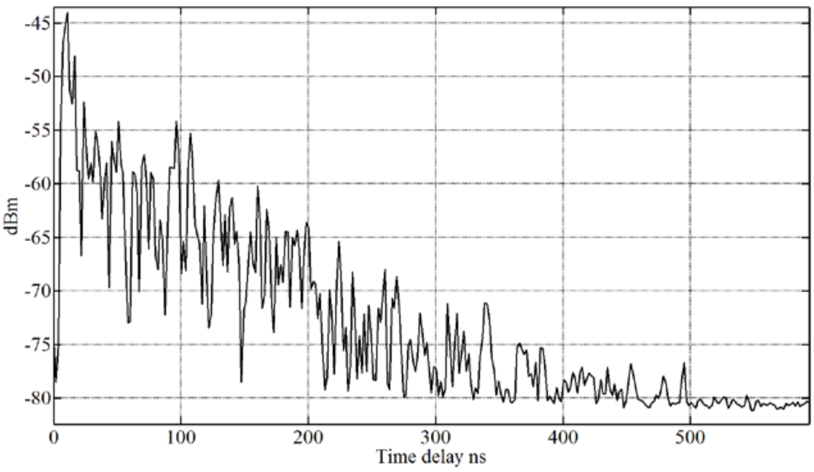
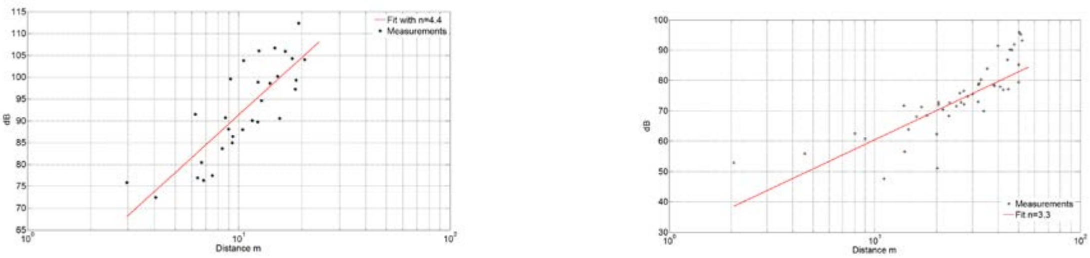


Fig. 6 PDP in the semi-shielded environment in iMinds

In addition, the path loss was estimated and the results for the TUB data with both transmit and receive antennas at ceiling height and for the iMinds environment are displayed in Fig. 7.a and Fig. 7.b with the estimated path loss exponent which is 4.4 for the TUB data and 3.3 for the iMinds environment.



(a) (b)

Fig. 7 Estimated path loss in (a) TUB and (b) iMinds with the path loss coefficient fit

5. Conclusions

In this paper an overview of the multi-band radio channel sounder developed at Durham University has been given. The sounder was used in measurements in the 60 GHz band for on body networks and in the ISM1 band in three test beds. Results of rms delay spread haven been presented for both bands and for the different environments. Path loss coefficients were also estimated for two of the environments and these were found to be 4.4 for the office environment when the antennas are placed close to the ceiling and 3.3 in the semi-shielded environment where a large number of reflectors are present due to the metallic structures.

6. Acknowledgements

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7. References

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