MEASUREMENTS IN THE 2-6 GHZ BAND

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ABSTRACT

Single input single output (SISO) and multiple input multiple output (MIMO) measurements at frequencies between 2-6 GHz have been performed using a specially designed and implemented multiple receive channel sounder. These include simultaneous SISO measurements at three frequency bands in rural environments and wideband MIMO measurements at two frequencies in a TV studio environment. The paper briefly discusses the architecture of the sounder and the results of the various measurements are presented.

INTRODUCTION

A dual band channel sounder with eight parallel receive channels has been designed and implemented to perform various single input multiple output SIMO and MIMO measurements at the two frequency division duplex bands of UMTS [1]. New wireless communication systems are being deployed in the bands above 2 GHz. Some of these systems may be operating within several possible bands in the unlicensed spectrum such as the 2.5 GHz, 3.5 GHz and 5.2/5.8 GHz bands. Successful deployment of commercial services in these bands will require an understanding of the propagation within various indoor and outdoor environments. To characterise these frequency bands, up-converters and down-converters with either a single channel or multiple receive channels have been designed and implemented. The upgraded channel sounder was then used to perform simultaneous frequency measurements at 2.5 GHz, 3.5 GHz and 5.8 GHz in rural areas for the characterization of WMAN channels with SISO configuration. These were performed with 10 MHz bandwidth, and subsequently processed with 5.7 MHz bandwidth for the 2.5 GHz and 3.5 GHz bands or with 10 MHz bandwidth for the 5.8 GHz band. The data were processed to determine various channel functions, which include the time variant frequency function, and the power delay profile. While the transfer function is preferred for the simulation of OFDM modulation as proposed for WMAN systems, the power delay profile can be used to determine the number of significant multipath components to use in a tapped delay line simulator.

MIMO measurements were performed either at a single frequency using up to eight receive channels or simultaneously at two frequencies using four receive channels at each frequency band. The single frequency measurements were carried out at the uplink frequency of UMTS using 60 MHz bandwidth [2], while the dual frequency measurements were conducted with 100 MHz bandwidth at 2.2 GHz and 5.8 GHz. These were mainly indoor measurements with the latter being performed in a typical TV studio. Results of the dual frequency measurements are presented here in terms of MIMO channel capacity for different antenna numbers.

MULTIBAND CHANNEL SOUNDER

The multi-band channel sounder designed and implemented for the purposes of the measurements, is based on the chirp sounder with eight parallel receive channels at the UMTS frequency division duplex bands (1920-1980 MHz and 2110-2170 MHz) with programmable bandwidth, waveform repetition frequency (WRF) and centre frequency [1]. For higher frequency bands, two separate units were designed and implemented which consist of up-converters and down converters, with either single channels or multiple channels. Fig. 1.a displays the block diagram for the single channel converter units whose output/input can be combined to feed a single antenna at both ends of the link or separate antennas as required. Fig. 1.b-c shows the realised transmitter and receiver with the converter units. The sounder can also be used in a number of other configurations which can be either single frequency band measurements with eight receive channels or four receive channels on two different frequencies as shown in Fig. 2 for the MIMO measurements performed in a TV studio.

The receiver of the sounder employs the heterodyne detector, which mixes the received chirp signal with a delayed replica. This results in a beat note for each multipath component, which can then be identified using spectral analysis. The technique compresses the signal in bandwidth and not in time, and since the frequency of a chirp signal is linearly related to time, the digitised signal can be processed for different frequencies and bandwidths by taking the relevant section. Using the fast Fourier transform (FFT) different channel functions such as the power delay profile, the scattering function, the Doppler spectrum, and the time variant transfer function can be obtained.

MULTIBAND SISO AND MIMO MEASUREMENTS

Field trials were performed in both indoor and outdoor environments at different frequency bands. Simultaneous SISO measurements at three different frequencies (2.5 GHz, 3.5 GHz and 5.8 GHz) with 10 MHz bandwidth, 250 Hz WRF and 1 s duration per location, were performed in a typical rural residential environment. Three separate transmit antennas were mounted on top of a tower and three separate omni-directional dipoles were used for reception. Simultaneous 4 by 4 MIMO measurements using the configuration of Fig. 3 were performed in a studio environment with 100 MHz bandwidth, 250 Hz overall WRF and 1 s per run. Due to the switching at the transmitter, the effective WRF per antenna is 50 Hz giving an unambiguous Doppler coverage of $\pm$ 25 Hz. The antenna arrays employed for these measurements were 4-element discone antennas, which covered the two measured frequency bands of 2.2 GHz and 5.8 GHz. The antennas were mounted around a circle with a radius of 6.5 cm resulting in 9.5 cm spacing between antennas. The measurement environments for both sets of measurements and the discone array used at the transmitter are shown in Fig. 2.

MEASUREMENT RESULTS

The multiple SISO measurements were processed for the computation of the power delay profiles and for the estimation of the time variant transfer function. The 2.5 GHz and 3.5 GHz measurements were processed with 5.7 MHz bandwidth, and the 5.8 GHz were processed with 10 MHz. An example of power delay profiles measured at the three frequencies is shown in Fig. 4 with the corresponding number of multipath components for a 20 dB threshold. The differences in the number of multipath components and their relative level is evident from the figure.; however, all three frequencies show a small delay spread on the order of 2 μs. Since the 5.8 GHz band was processed with 10 MHz the number of detected multipath components is generally higher than the other two bands.

The stationary and dynamic MIMO measurements were processed to compute the channel capacity for 2 by 2 and 4 by 4 antenna arrays. The capacity was computed from the time variant channel transfer function using the following equation

$$C_{WB} = \frac{1}{N}\sum_{i=1}^{N}\log_2\left[\det\left(\mathbf{I}_{n_R} + \frac{\rho}{n_T}\mathbf{H}_i\mathbf{H}_i^H\right)\right] \tag{1}$$

where the transfer function for each frequency was normalised with respect to the overall sample norm (N snapshots) i.e. $\mathbf{H}^{(f_n)} = \beta\hat{\mathbf{H}}^{(f_n)}$. Here f_n represents the frequency sample index and β represents the normalisation constant for each snapshot, given by

$$\beta = 1\Big/\sqrt{\left(\frac{1}{N\cdot n_R n_T}\sum_{f_n=1}^{N}\sum_{i=1}^{n_R}\sum_{j=1}^{n_T}\left|\hat{H}_{ij}^{(f_n)}\right|^2\right)} \tag{2}$$

An example of a time variant MIMO channel for the two frequency bands is shown in Fig. 5, which displays the scattering function. The measurements were divided into line of sight and non line of sight and Fig. 6 displays the capacity results for the 2.2 GHz band for 30 dB signal to noise ratio. The results indicate an increase in the median capacity of about 5-13 b/s/Hz for the 2 by 2 and 4 by 4 antenna arrays for the NLOS case over the LOS locations.

CONCLUSIONS

The architecture of a multi-band multi-channel chirp sounder was briefly presented. The sounder was used in both multiple frequency SISO measurements and dual frequency MIMO measurements. The SISO measurements were performed in a rural environment where WMAN are likely to be used. The data were processed with 5.7 MHz and 10 MHz bandwidth, depending on the allocated spectrum for the relevant frequency band. The number of multipath components was subsequently computed for 20 dB threshold to determine the number of taps to be used in a tapped delay line simulator. Generally, the delay spread in most locations was limited to within 2 μs and the number of multipath components was between 3-4. The MIMO measurements were conducted with 100 MHz bandwidth in LOS and NLOS locations in a studio environment with both static and dynamic channels. The channel capacity was subsequently computed for 2 by 2 and 4 by 4 antenna combinations and the capacity of the LOS (correlated channels) showing a significant reduction in capacity.

REFERENCES

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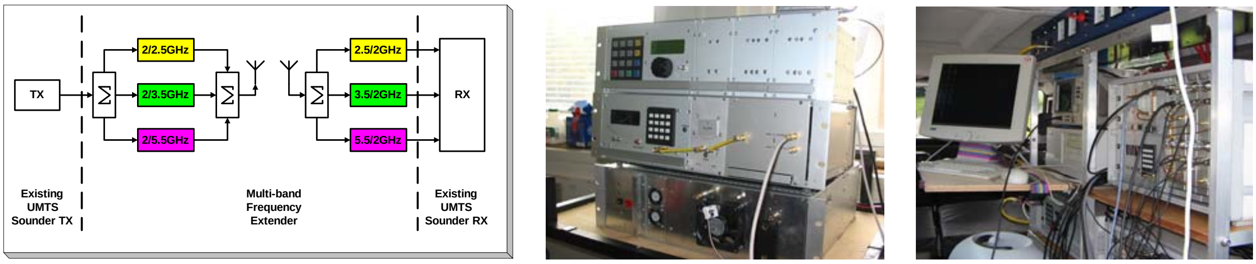
[2] N. Razavi-Ghods, M. Abdalla, S. Salous, Characterisation of MIMO propagation channels using directional antenna arrays, presented at 3G2004 conference, London, UK, October 2004.



(a) (b) (c)

Fig. 1. (a) block diagram of converter units, (b) transmitter, (c) receiver

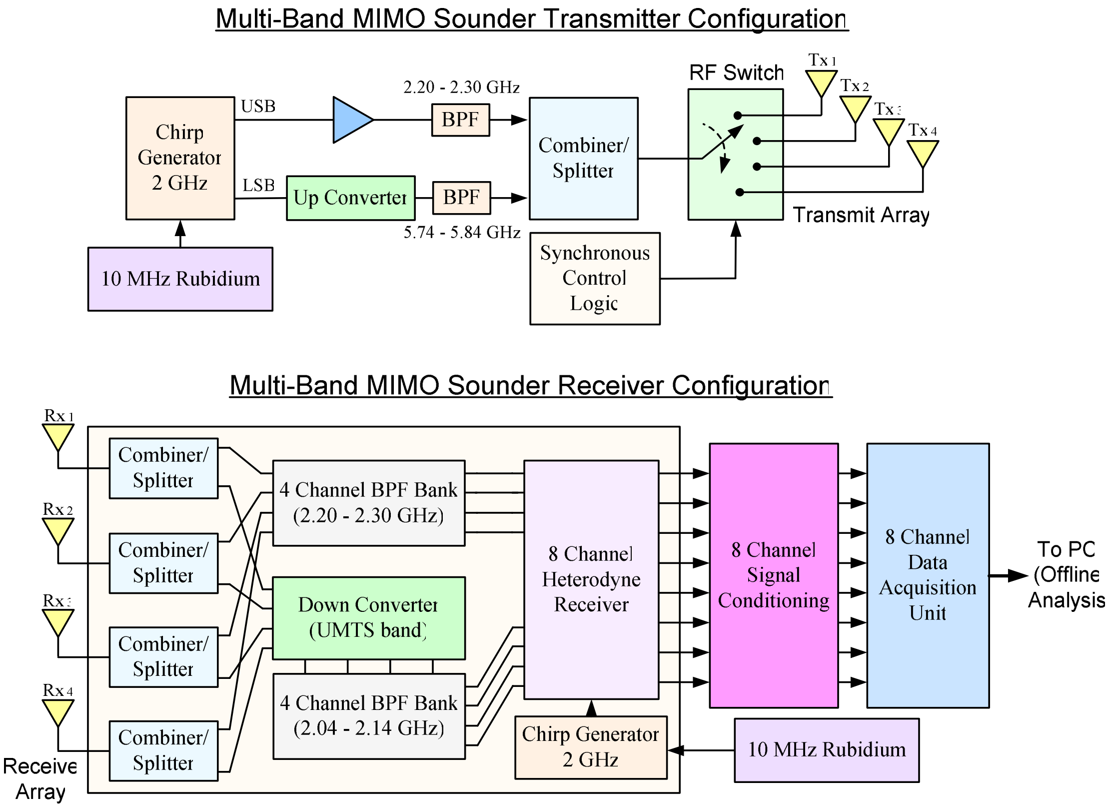
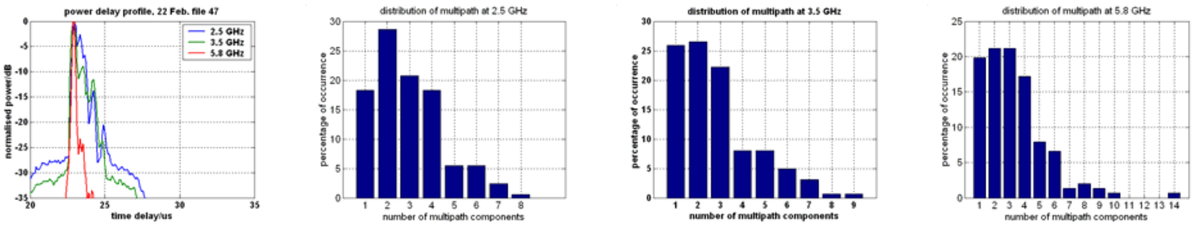


Fig. 2. Block diagram of sounder used for 4 by 4 dual band MIMO measurements

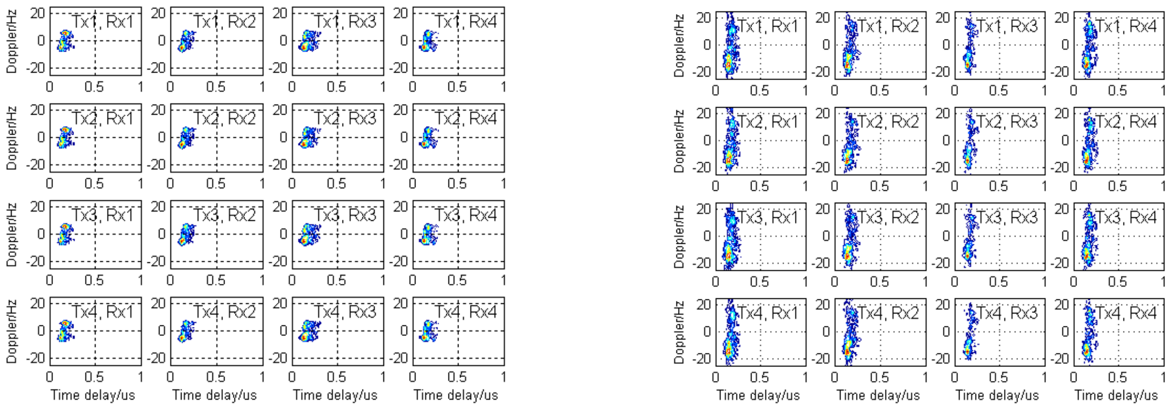
(a) (b) (c)

Fig. 3. (a) Rural environment for SISO measurements, (b) TV studio for MIMO measurements, (c) 4 by 4 array



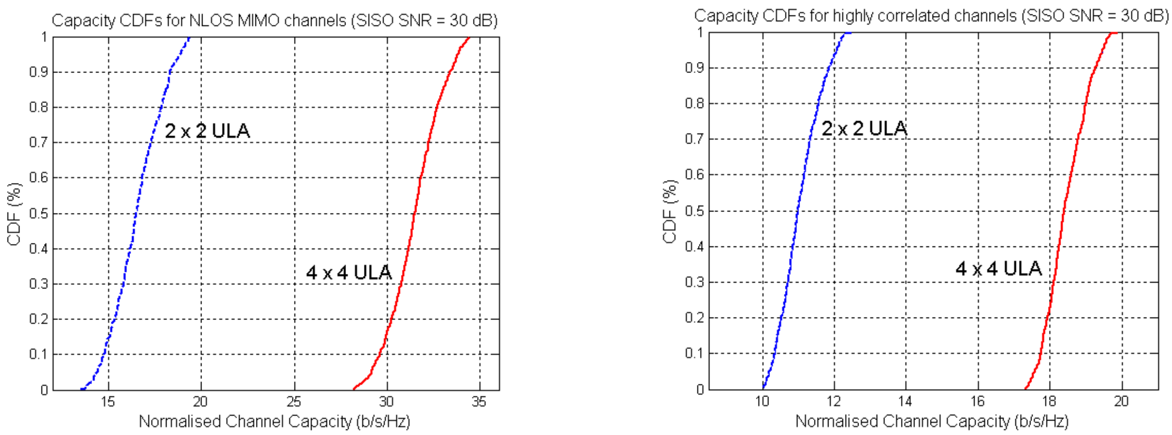
(a) (b) (c) (d)

Fig. 4. (a) Power delay profiles, number of multipath components at (b) 2.5, (c) 3.5 and (d) 5.8 GHz



(a) (b)

Fig. 5. Dynamic scattering MIMO functions (a) 2.2 GHz, (b) 5.8 GHz



(a) (b)

Fig. 6. MIMO capacity for (a) NLOS channels, (b) correlated channels