

State of the art mobile radio channel sounding and data analysis

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Abstract

Radio channel measurements are fundamental for the design of wireless communication networks. As higher data rates are required to provide immersive user experiences and heterogeneous networks are expected to dominate the next generation of cellular networks, multi-band channel sounders are needed to provide the necessary measurements for the design of such systems. In this tutorial the requirements of wideband channel sounding in multiple bands from low frequencies in the TV band to the mmWave band are outlined. Examples of state of the art channel sounder architectures which enable both active radio propagation measurements and passive spectrum monitoring are discussed. Active measurements are enabled through the transmission of a wideband signal using either single or multiple antennas and reception with either single or multiple antennas for the characterisation of multipath parameters such as time delay spread and angular spread. The estimation of path loss and shadowing effects are also enabled through such measurements. As the demand for spectrum efficiency increases, spectrum sensing for cognitive radio applications is increasing in importance. Channel sounders which employ a fast frequency sweep can be used in the passive mode to sense the occupancy of the spectrum and to model and predict the availability of the spectrum in space, time and frequency.

I. Channel sounding techniques

Wideband measurements can be performed using off the shelf equipment such as a vector network analyser in conjunction with wideband antennas [1-3]. Since the analyser is used for transmission and reception, long range measurements are enabled using optical converters and optical cables. For multiple antenna measurements multiple port network analysers or an RF switch can be used to switch in the different antenna elements. Network analysers have a limited number of frequency points typically on the order of 1600 points and require a few ms to perform the frequency sweep. Hence their applicability is limited to the quasi stationary environment in particular when used for multiple antenna measurements. Their advantage lies in the ease of setting up the experiment and acquiring calibrated data. Network analysers are particularly suited for ultra-wideband (UWB) measurements in indoor environments where the required bandwidth can span several GHz. An alternative to network analysers is the use of fast frequency sweeps generated using direct digital frequency synthesisers (DDFS) and other digital synthesis techniques which enable measurements of the time variability of the channel. Using separate sweepers at the transmitter and receiver enable dynamic measurements as well as free movement between floors without cables and outdoor measurements. With the advent of high speed electronics current DDFS's are capable of generating sweeps in excess of 1 GHz in a few μ s. Alternatively, arbitrary waveform generators using high speed memory devices also provide the possibility of generating high bandwidth frequency sweep waveforms. Current generators can be clocked at 8 GHz providing bandwidths up to 4 GHz. Due to the high speed requirements the memory tends to be very limited in size which restricts the duration of the waveform. Pseudo Random Binary Sequences using high speed logic have now also become commercially available and these provide the capability of UWB signals up to 5 GHz bandwidth and up to 214 ns time delay window [4]. For such applications, a high speed digitising oscilloscope is used to acquire the data or a sliding correlator can be implemented to reduce the requirements of the data acquisition unit. Similarly for fast frequency sweepers, bandwidth compression can be implemented through heterodyne detection of the received signal where a delayed replica of the transmitted sweep is mixed with the incoming signal to generate low frequency beat notes.

An alternative to using active measurements which require both transmitter and receiver, passive measurements can be performed using RF converters to baseband and digitising the inphase and quadrature components, frequency sweepers, and digitisers, or spectrum analysers to monitor transmissions of other users. An example of this monitoring is illustrated in Figure 1 which displays the 3G downlink spectrum which covers 60 MHz bandwidth in 5 MHz sections per user. Since the transmitted signal is spread spectrum measuring the received signal provides frequency selectivity information of the received signal and penetration loss and coverage without the need for transmission.

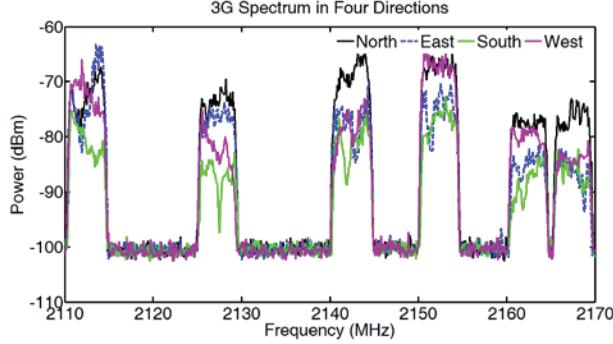


Figure 1. Spectrum sensing of the 3G down link using four directional antennas

II. Data analysis

Data can be analysed to extract a number of channel parameters most common of these is the rms delay spread and coherent bandwidth estimated from small scale channel measurements. These can be accumulated over large areas to obtain the large scale characterisation of the channel. Small scale parameter estimation is based on the assumption of wide sense stationary uncorrelated scattering. The selection of the time window/spatial distance for the estimation of channel parameters to meet these assumptions is discussed.

Although traditionally path loss measurements are performed with CW measurements, wideband measurements also enable the estimation of shadowing and path loss. The estimation of path loss from wideband data will be presented.

Massive multiple input multiple output MIMO is envisaged as a key enabler of future wireless networks. The tutorial will also discuss the estimation of MIMO capacity from measurements such as that shown in Figure 2 for a 4 by 4 MIMO measurement.

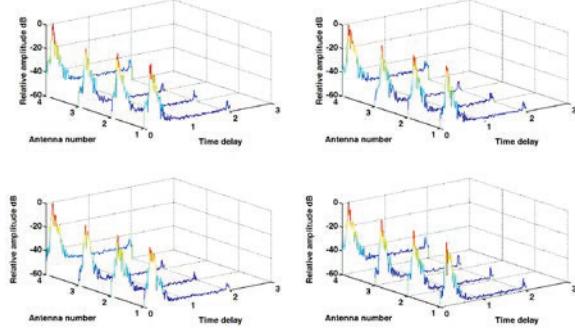


Figure 2. Example of 4 by 4 MIMO measurement in an indoor environment

As interest in mmWave increases examples of measurements from wideband on body networks and indoor environments in the 60 GHz band will be presented highlighting the shortcomings of using a VNA for such measurements and comparing VNA results with high speed channel sounders.

References

- [1] Cuinas, I., and Garcia Sanchez, M., " Measuring, modelling and characterising of indoor radio channel at 5.8 MHz ", *IEEE Transactions on Vehicular Technology*, Vol. 51, No. 2, March 2001, pp. 526-535.
- [2] Bultitude, R.C., Melancon, P., Zaghloul, H., Morrison, G., and Prokki, M., "The dependence of indoor radio channel multipath characteristics on transmit/receive ranges", *IEEE Journal on Selected Areas in Communications*, Vol. 11, No. 7, September 1993, pp. 979-989.
- [3] M. Wegmuller, J. P. von der Weid, P. Oberson, and N. Gisin, "High resolution fiber distributed measurements with coherent OFDR," in *Proc. ECOC'00*, 2000, paper 11.3.4, p. 109.
- [4] <http://www.centellax.com/products/testmeas/accessories/TG2P1A.shtml>