ADAPTIVE CHANNEL ESTIMATION FOR SPARSE ULTRA WIDEBAND SYSTEMS

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In memory of my brother, Enoch (1976-2013)
and dedicated to my parents.

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ABSTRACT

Increased research in ultra wideband (UWB) systems in the last two decades has established it as a technology for high-speed, short-range applications. UWB also offers low power consumption, immunity to multipath fading, increased security, and low interference in multipath environments. Unfortunately, it is a great challenge to obtain accurate channel state information at the receiver side of UWB systems, especially in time-varying applications. Consequently, this research deals with the design of an adaptive channel estimation algorithm for sparse UWB systems. Using measurement data, this thesis considers the estimation of a long sparse multipath channel in a mobile UWB system. Recent advances in Compressive Sensing (CS) applications in signal processing make CS to be a legitimate candidate for processing sparse signals. Among the broad application areas of CS is channel estimation. Based on the objectives of the research, the contributions of this thesis are in three parts. Firstly, channel measurements usually provide accurate Channel Impulse Response (CIR), which helps to accurately model any channel behaviour. Thus, this thesis provides channel measurements in various mobile line-of-sight scenarios to precisely measure the efficacy of the proposed channel estimation algorithm. Secondly, traditional channel estimation algorithms like the Least Mean Square (LMS) and Normalised LMS (NLMS) algorithms do not consider the structural information of the channel. In addition, CS-based LMS and NLMS algorithms do not consider the use of the channel sparsity to control the algorithm performance. Therefore, this thesis also proposes a number of Sparseness-Controlled (SC) LMS and NLMS algorithms for estimating sparse UWB channels. Lastly, the thesis presents an analysis of the performance of the proposed estimators in terms of the Mean Square Error (MSE), steady-state excess MSE, convergence speed, robustness, and computational complexity. Simulation results show that unlike traditional algorithms, the proposed estimators perform better to improve the estimation of the CIR of sparse UWB channels. Even though, for all the scenarios considered, compared to the SC-l_0-Norm NLMS (SC-L0-NLMS) algorithm, the SC-reweighted zero-attracting NLMS (SC-RZA-NLMS) algorithm provides excellent performance, the SC-ZA-NLMS algorithm is less computationally complex than both and it performs in close proximity to both at higher SNR. For the sparse channel, when SNR is 30 dB, the SC-ZA-NLMS algorithm converges faster with better MSE of -38.2391 dB compared to the SC-RZA-LMS algorithm, which converges at -33.9805 dB. Therefore, the SC-ZA-NLMS algorithm is the most suitable for accurately estimating the sparse UWB channel.

ABSTRAK

Peningkatan penyelidikan dalam sistem jalur lebar ultra (UWB) dalam dua dekad sebelum ini telah menetapkan ia sebagai satu teknologi untuk aplikasi berkelajuan tinggi, jarak dekat. UWB juga menawarkan penggunaan kuasa yang rendah, imuniti kepada pemudaran pelbagai arah, keselamatan dipertingkatkan dan gangguan dalam persekitaran pelbagai arah yang rendah. Malangnya, ia adalah satu cabaran besar untuk mendapatkan maklumat keadaan saluran yang tepat di bahagian penerima sistem UWB, terutamanya dalam aplikasi masa yang berbeza-beza. Maka, penyelidikan ini berkaitan dengan reka bentuk suatu algoritma anggaran saluran mudah suai untuk sistem UWB jarang. Menggunakan data pengukuran, tesis ini menganggap anggaran saluran pelbagai arah jarang yang panjang dalam sistem UWB mudah alih. Kemajuan terkini dalam aplikasi Mampatan Penderiaan (CS) pemprosesan isyarat menjadikan CS menjadi calon yang sah bagi pemprosesan isyarat jarang. Antara bidang aplikasi CS yang meluas adalah anggaran saluran. Berdasarkan objektif kajian, sumbangan tesis ini berada dalam tiga bahagian. Pertama, pengukuran saluran biasanya menyediakan Saluran Tindak Balas Denyut (CIR) tepat, yang membantu untuk model dengan tepat mana-mana tingkah laku saluran. Oleh itu, tesis ini menyediakan pengukuran saluran dalam pelbagai senario garis nampak mudah alih yang membantu mengukur keberkesanan algoritma anggaran saluran yang dicadangankan dengan tepat. Kedua, algoritma anggaran saluran tradisional seperti algoritma Min Kuasa Dua Terkecil (LMS) dan LMS Ternormal (NLMS) tidak mempertimbangkan maklumat struktur saluran. Selain itu, CS berasaskan algoritma LMS dan NLMS tidak mempertimbangkan penggunaan jarang saluran untuk mengawal prestasi algoritma. Oleh yang demikian, tesis ini juga mencadangkan beberapa Kawalan Kejarangan (SC) algoritma LMS dan NLMS untuk menganggar saluran UWB jarang. Akhir sekali, tesis ini membentangkan analisis prestasi penganggar yang dicadangkan dari segi Ralat Min Kuasa Dua (MSE), keadaan seimbang berlebihan MSE, kelajuan penumpuan, keteguhan, dan kekompleksan pengkomputeran. Keputusan simulasi menunjukkan bahawa tidak seperti algoritma tradisional, penganggar yang dicadangkan melaksanakan lebih baik untuk meningkatkan anggaran CIR jarang saluran UWB. Walaupun, untuk semua senario yang dipertimbangkan, berbanding dengan algoritma SC-l_0-norma NLMS (SC-L0-NLMS), algoritma SC-pemberat semula penarikan-sifar NLMS (SC-RZA-NLMS) yang menyediakan prestasi yang sangat baik, algoritma SC-ZA-NLMS yang kurang kompleks pengkomputeran daripada kedua-duanya dan dilaksanakan berdekatan dengan kedua-duanya pada SNR yang tinggi. Untuk saluran yang jarang, apabila SNR ialah 30 dB, algoritma SC-ZA-NLMS menumpu lebih cepat dengan MSE lebih baik iaitu -38.2391 dB berbanding dengan algoritma SC-RZA-LMS, yang menumpu pada -33.9805 dB. Oleh itu, algoritma SC-ZA-NLMS adalah yang paling tepat untuk menganggar saluran UWB jarang.