Experimental Wideband Time Reversal of Microwaves

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Time reversal (TR) has been studied for a quite long time in ultrasound, and it has been shown that it is able to focus both in space and time a wave. In a recent paper we have shown that it is possible to time-reverse microwaves without the need to fully digitize the impulse response as it is done with ultrasound. In fact the interesting part of a radio frequency modulated signal being in its complex envelop, one has only to digitize the baseband impulse responses, to time reverse them and phase conjugate the carrier. This allowed the study of such a process with high frequencies using nowadays electronic components, but it was carried with a narrow bandwidth (2 MHz). TR communications have first been successfully performed with acoustic signals in underwater schemes. Recently we have studied the use of ultrasonic TR in a small-scaled indoor environment to characterize its benefits and drawbacks when doing ultra wide band communications. We have underlined that it drastically decreases the time spreading of the signals and allows spacial focusing of the information. The drawbacks are that it also creates inter-symbol interferences due to the fact that the medium is never exactly symmetric in time and that the number of sensor is never infinite. Some of these characteristics have also been addressed theoretically for the electromagnetic case. In this presentation we go further in the study as we developed a wide bandwidth time reversal mirror (up to 250 MHz of bandwidth) in order to have all information on the temporal and spatial focusing properties and to do the first real experiments of wideband TR communications. To that end, we have used separated components that were available commercially. The carrier frequency is generated at 2.45 GHz, the baseband signals come from a dual channel arbitrary waveform generator with 1 GS/s sampling, the modulation is achieved with an IQ modulator with a bandwidth of 250 MHz. The acquisition of the signals is made with a 4-channel 20 GS/s sampling digital scope. The down conversion and processing of the data is achieved numerically with Matlab because nowadays commercial demodulators have smaller bandwidth than the one we needed. In addition to this setup, which stands for a single channel time reversal mirror (TRM), we used two 8-channels switches in order to emulate a 8 channel TRM by linearity, the 8 other antennas being used as receiving antennas. This setup allowed us to study different part of electromagnetic TR process which will be described in this paper. All the experiments were conducted in an electromagnetic reverberating room with a Q factor of 30, because the emitting power of the setup did not allow in-room experiments. Further work will be done in a typical indoor setup, with a more powerful amplifier. In a first part, the temporal compression is investigated as a function of the bandwidth and the number of emitting antennas. A special attention is given to the gain in amplitude that is due to the TR temporal compression in terms of signal to external noise ratio. The effect of the correlation between antennas is also discussed and its effect on the TR sidelobes is shown. In the second part a clear evidence of the spatial focusing of a TR experiment is given. To that end, the 8 channel TRM is used to send a pulse on one antenna of a 8 antenna array receiver. The 8 receiving antennas are quarter-wavelength antennas on a ground plane. That way the field is scanned in the neighborhood of the focus point with model antennas. The result is compared to the analytical functions for spatial correlations of electromagnetic fields in 3 D, while taking the coupling into account. Finally, using the results of the above sections, the 8 channel TRM is used to send information to between 1 and 8 receivers that are 0.5 wavelength apart. It is shown that although no precoding nor error correcting code are used, high data rate communications can be achieved with a significant binary error rate, especially in a noisy environment.