Time-domain models for signal distortion in UWB arrays

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Impulse-radiating arrays have been recently proposed for several Ultra-Wideband applications [M.G.M Hussain, IEEE Trans. Vehicular Tech. 51, 393-403, 2002] exploiting their advantages in terms of reduced side-lobes and high resolution. These systems are driven by pulsed waveforms and their scanning performances are controlled by inter-element time delays. Preliminary physical investigations have been reported in [A. Shlivinski, E. Heyman, Ultra-wideband short-pulse electromagnetics 5, 327-334, 2000], where coupling between radiating elements is usually neglected and emphasis is mainly devoted to conditions for side lobe absence. It is here proposed a simple physical model of the time domain coupling for impulse-radiating arrays taking into account the scanning features, the input signal shape, the repetition rate of the input pulse train and finally the impulse response of the single antenna. A set of N identical antennas, whose position is tagged by $\boldsymbol{r}_n$ vectors are sourced by an inward travelling current $i_n^+(\tau)$. Denoting with $\boldsymbol{h}^t(\hat{\boldsymbol{r}}, t)$ the TD effective height describing the antenna dynamics, a TD *active array factor* can be introduced as:

$$\mathcal{F}_A(\hat{\boldsymbol{r}}, \tau) = \sum_{n=1}^{N} i_n^+(\tau + t_n(\hat{\boldsymbol{r}})) - \sum_{n=1}^{N} \gamma_{L,n}(\tau) * \sum_{\substack{m=1 \\ m \neq n}}^{N} s_{nm} * i_m^+(\tau + t_n(\hat{\boldsymbol{r}}))$$

where $\gamma_{L,n}(\tau)$ is the *embedded reflection coefficient operator* of the nth antenna, $t_n(\hat{\boldsymbol{r}}) = \frac{\boldsymbol{r}_n \cdot \hat{\boldsymbol{r}}}{c}$, and $s_{nm}(\tau)$ is a *coupling operator* which accounts for the multiple bouncing among the antennas under perfect matching condition. The second summation describes the echoes coming from each mth antenna and re-radiated by the $(k \neq m)$th one. This function is therefore a distorting operator which, in some condition, could modify the radiated signal waveform. Above equation will be detailed discussed through analytical investigations and fullwave numerical examples. Some relevant results are that the coupling echoes are delayed with respect to direct pulses and therefore the distorting effect of the coupling depends on the finite duration of the antenna input signal and on the scanning direction. The analysis has permitted to obtain guidelines about the choice of electrical and geometrical parameters (see Fig.1) with the purpose to reduce the coupling distortion for a given scan angle, even with very dense arrays.

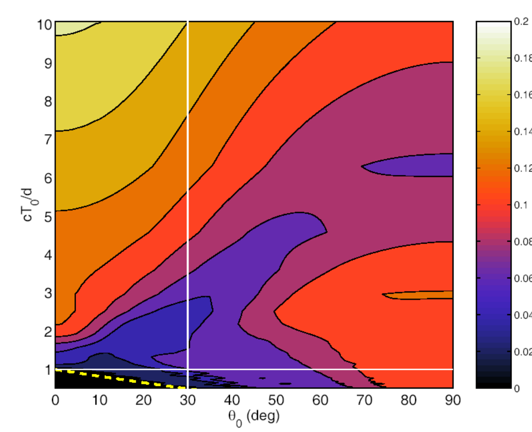

Figure 1: Signal distortion for a four-elements array, measuread as the r.m.s. difference between the radiated signal including and neglecting the coupling, v.s. the array spacing d, the scanning angle θ_0, and the pulse duration T_0.