Dispersive Properties of Terminal-Loaded Dipole Antennas in UWB Link

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Introduction

In this study, the effect of resistive antenna port terminations is explored for controlling dispersive properties of antennas and meeting several design objectives for signals at the receiver load, including transmission efficiency, peak voltage, and signal confinement in time. This work supplements typical UWB design and analysis, which often focuses on antenna and signal issues [1-3]. The results are illustrated for antenna structures like those sketched in Fig. 1. The main research results of this study are given in 3:1 band using normalized time and frequency units that make them scalable to any physical band of interest.

Full-Wave and Circuit Two-Antenna Link Model

A simplified link model, Fig. 1b, includes two antennas at the link ends, the transmitter represented by the voltage source $V_G(\omega)$ with the internal impedance Z_G and the receiver that is just the load impedance Z_L. For the present study, the link antennas operate in the far field with respect to each other and are ideally aligned in terms of their polarizations and maximum gain directions. The link transfer function, with angular dependencies suppressed, is defined as the voltage ratio

$$H_{LG}(\omega) = V_L(\omega, R) / V_G(\omega) / H_{F.S.}(\omega, R) \qquad (1)$$

and is normalized by removing the free-space propagation factor to ensure distant-independent accuracy of the numerically predicted data

$$H_{F.S.}(\omega, R) = \exp(-jkR) / R \qquad (2)$$

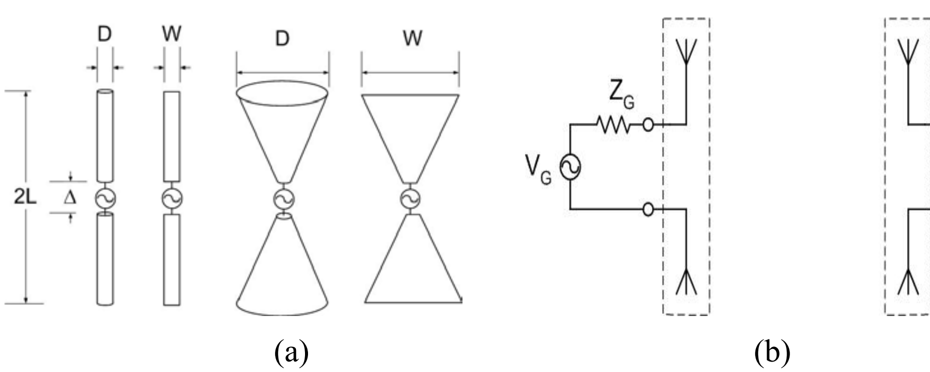

Fig. 1. (a) Geometrical templates for several practical dipoles including 3-D solid and 2-D flat structures with parameterized length *L*, diameter *D* and width *W*. (b) Two-antenna link model with transmitter generator and receiver load connected to antenna ports.

Numerical Results for Link Figures of Merit

A Method of Moment solver is used to compute the quantity (1) for a number of different resistive terminations at the transmitter, R_G, and receiver, R_L, link ends in the range 10…1000 Ω. Then, the link performance is evaluated using (1) for a set of link merits including (i) peak voltage at the receiver load, (ii) transmission efficiency as a ratio of the energy delivered at the receiver load to the energy available from the generator, (iii) time confinement of the received energy and (iv) standard deviation of the group delay time as a measure of distortion. The transmitting antenna is excited by a set of time-harmonic signals of unit amplitude in the given band *BW* of interest $V_G(\omega)=1$ if $\omega \in \mathrm{BW}$ and $V_G(\omega)=0$ if $\omega \notin \mathrm{BW}$. Similarly, arbitrary driving signals can be considered [3]. For illustration, the *BW* is set to 3:1 in terms of the normalized frequency. Two cases with thin wire *L/D*=100 and bowtie *L/W*=1 dipoles are simulated and plotted in Fig. 2 for the figures of merit specified above. Noting the regions of optimum performance in Fig. 2 (lighter color), the design objectives can be mutually exclusive with respect to the specified port resistive terminations, requiring some trading in practical multi-objective UWB link design with real dispersive antennas.

Effect of Ports Resistive Loads on Received Signals

The data in Fig. 2 show regions of optimum port terminations for particular design objectives. Three such cases and one reference case of R_G=R_L=100 Ω are in Fig. 3. In particular, maximizing the received peak voltage is achievable only with asymmetrical resistors R_G=10 Ω and R_L=1000 Ω at the cost of lowered transmission efficiency. The maximum energy efficiency is provided by symmetrical loading at both the link ends that depends on a specific antenna structure, viz. R_G=R_L=750 Ω for the thin wire, and R_G=R_L=300 Ω for bowtie. The optimized temporal bounds on the delivered energy confinement and group delay time deviation can be nearly the same for the thin-wire and bowtie structures when they are properly terminated.

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References:

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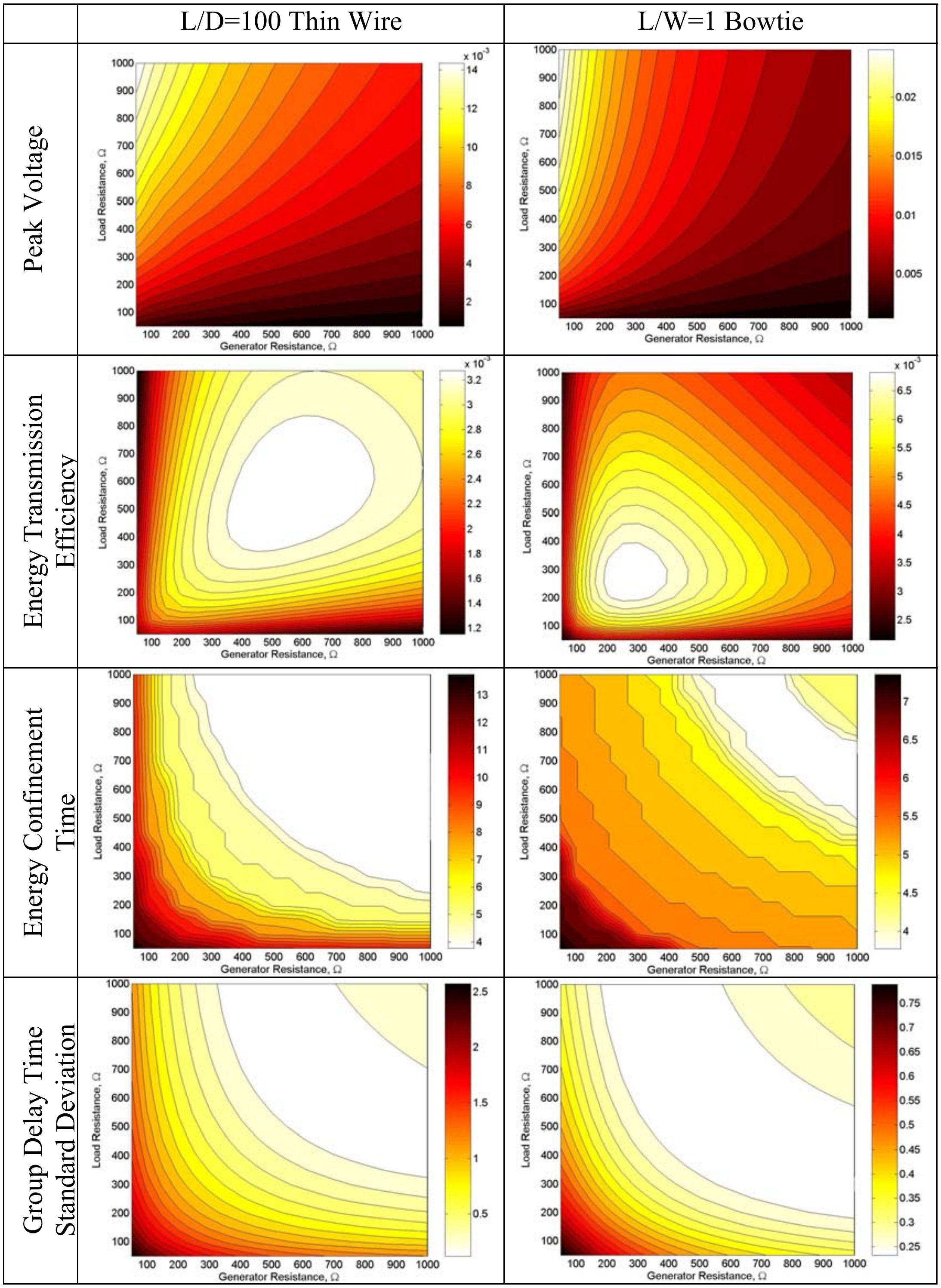

Fig. 2. Link performance measures versus the resistive loads for thin wire (*L/D=100*), at the left, and flat bowtie (*L/W=1*), at the right. Peak voltages are multiplied by *R* from (2). Energy transmission efficiencies are multiplied by R^2 from (2). Time units are multiplied by $1/\tau_0$, where $\tau_0 = L/c$ is traveling time along the dipole arm, Fig. 1a.

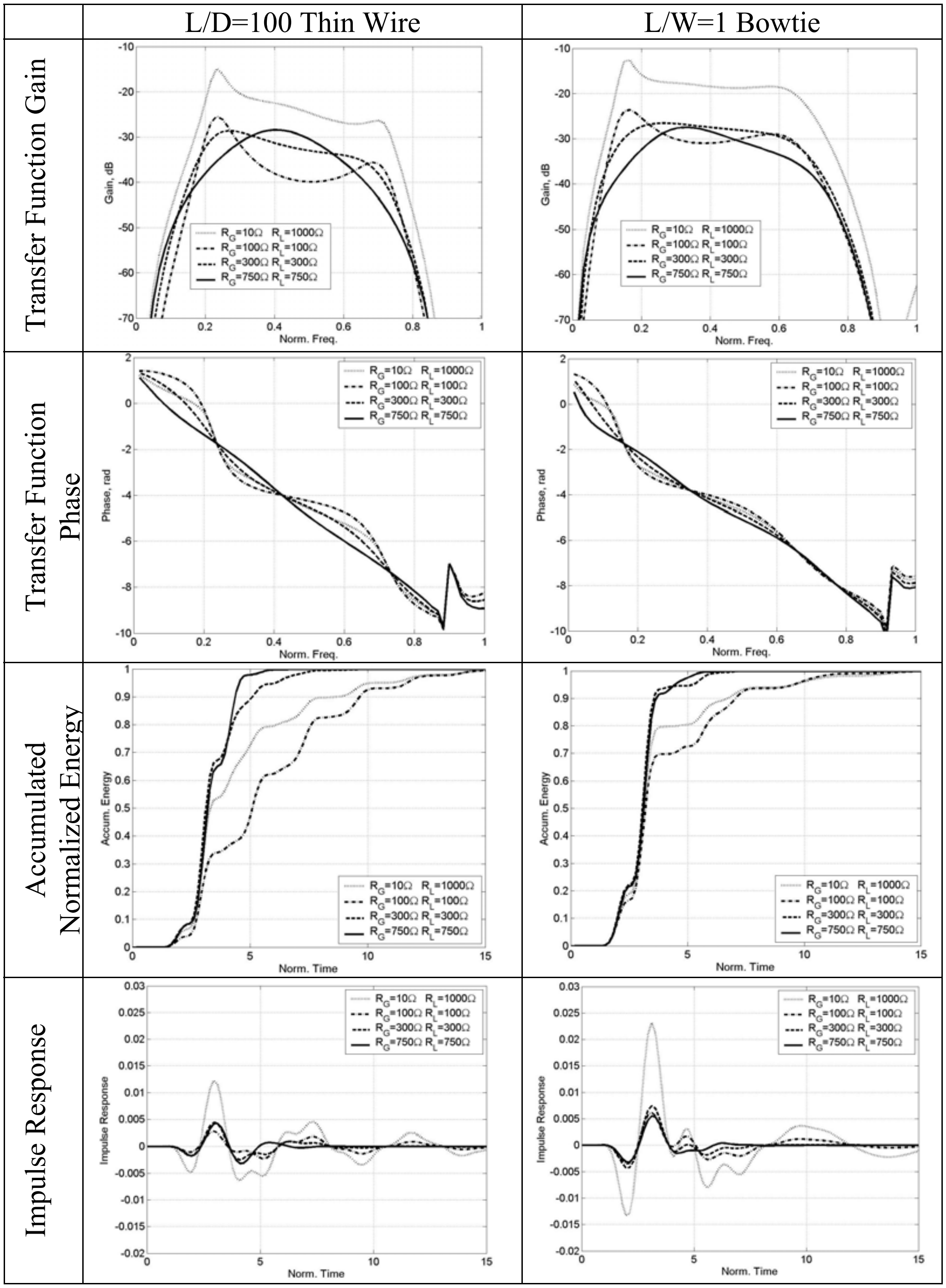

Fig. 3. Frequency- and time-domain transfer characteristics for the thin-wire (L/D = 100), at the left, and bowtie (L/W = 1), at the right, for port resistive loads that optimize the figures of merit. The normalized frequency f^* and time units t^* are scaled as $f^* = f{\cdot}\tau_0$ and $t^* = t/\tau_0$, respectively, where $\tau_0 = L/c$ is traveling time from the antenna driving point to its open end, Fig. 1a (c is the free-space light speed). The normalization (2) is applied to the gain and impulse response.