Time-Domain Characterization of Straight Thin-Wire Antennas

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The time-domain response of a straight thin-wire antenna can be represented by the convolution of three functions, a *y*-function, which is the Fourier transform of the admittance at the feed point, an **h**-function, which is the Fourier transform of the time derivative of the effective length, and the source excitation voltage. The first two functions, when convolved together, form a response or **r**-function. This function gives the electric field due to an impulse voltage source and therefore characterizes the antenna as a transmitter. It also gives the time derivative of the received current due to an incident electric field impulse, and therefore characterizes the antenna as a receiver. A link between two such dipoles is characterized by a convolution of the respective transmit and receive **r**-functions, an integration with respect to time, and multiplication by a scale factor inversely proportional to the separation. This gives the impulse response of the entire link, which, when convolved with the source function, gives the received current in the load. It is instructive to explore these *y*, **h** and **r**-function characterizations for different wire lengths, and to predict the response for an infinite wire. We can do this analytically for simple cases, or by using detailed moment method modeling in other cases. To simplify the presentation of the results we consider the functions at an observation point normal to the axis of the wire.

An isolated **current element** has, by definition, a *y*-function that is a delta function. The **h**-function is the time derivative of a delta function, which can be deduced from the Fourier transform of the frequency-domain expression for the electric field. Therefore the **r**-function of a current element is the time derivative of a delta function. A **short dipole**, which has a triangular current distribution at all frequencies, has an admittance dominated by capacitance, therefore the *y*-function is the time derivative of a delta function. The **h**-function, also deduced from the frequency-domain electric field expression, is again the time derivative of a delta function. Therefore the **r**-function of a short dipole is the second time derivative of a delta function. A **finite length dipole**, with a reflection-matched source resistor, has a *y*-function that is essentially a positive impulse function followed by a lesser magnitude negative impulse function separated by the source-to-tip travel time. The **h**-function is a series of impulses of alternating sense and decreasing amplitude (due to radiation damping). Therefore the **r**-function of a finite length dipole, by convolution, is a triplet of impulse functions, two positive pulses separated by twice the source-to-tip travel time, and one negative pulse in the centre. The sum of the positive and negative values equals zero. The response approaches that of a short dipole as the length decreases. An **infinite length dipole** has *y*, **h** and **r**-functions consisting of only a single impulse, in each case equivalent to the first of the pulses for a finite length dipole. This is an exact representation for a tapered thin-wire and approximate for a constant (thin) radius wire. The impedance of an infinite wire dipole can be deduced by taking the inverse Fourier transform of the *y*-function pulse. A **sinusoidal current filament dipole** cannot be evaluated directly, but functions related to the *y* and **h**-functions illustrate the impossibility of achieving this case physically.