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An Overview of Ultrawideband Antennas

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Abstract

Conventionally, the design of antennas is narrowband and little attention is paid to the phase responses of the devices as functions of frequency. Even the use of the term broadband is misleading as one essentially takes a narrow band signal and sweeps it across the band of interest. In fact, it is not necessary to pay too much attention to the phase for narrowband signals, as the role played by the frequency factor is that of a scalar multiplier. However, if one now wants to use multiple frequencies and attempts to relate the data obtained at each frequency, then this frequency term can no longer be ignored. Depending on the application, this scale factor can actually have significant variations, which also depend on the size and the shape of the bandwidth over which the performance of the system is observed. In the time domain, the effect of this frequency term creates havoc as it provides a highly nonlinear operation and hence must be studied carefully. By broadband we mean temporal signals with good signal integrity. When it comes to waveform diversity, which implicitly assumes time-dependent phenomena, it is not possible to do any meaningful system design unless the effects of the antennas are taken into account. These effects will be illustrated in terms of the responses of the antennas and on the applicability of the current popular methodology of time reversal for the vector electromagnetic problem.

To provide a background, notions of bandwidth will be discussed, especially in light of recent interest in ultrawideband (UWB) systems ? the last decade has witnessed significantly greater interest in UWB radar. In that time, more than 15 nonmilitary UWB radars have been designed and fielded, which include applications to forestry, detecting underground utilities, and humanitarian demining. Since an antenna is an integral part of sensing systems, selected highlights of UWB antenna development will be very briefly summarized. It will also be illustrated how to design a discrete finite time domain pulse under the constraint of the Federal Communications Commission (FCC) ultra-wideband (UWB) spectral mask. This pulse also enjoys the advantage of having a linear phase over the frequency band of interest and is orthogonal to its shifted version of one or more baud time. The finite time pulse is designed by an optimization method and concentrates its energy in the allowed bands specified by the FCC. Finally, an example is presented to illustrate how these types of wideband pulses can be transmitted and received with little distortion.

Some fundamental problems in studying concepts involving the responses of antennas in the time domain are related to our subconscious definition of reciprocity. In the frequency domain, reciprocity is related simply to the fact that the spatial response of the sensor in the transmit mode is EQUAL to the spatial response of the sensor in the receive mode at any frequency of interest. In the time domain, the spatial response of the sensor will be time dependent. Hence, both the transmit and the receive impulse responses of the sensor will be a function of azimuth and elevation angles. However, for a fixed spatial angle, the transmit impulse response is NOT EQUAL to the receive impulse response of ANY sensor. In fact, mathematically one can argue that the transmit impulse response is the time derivative of the receive impulse response for any sensor. One may then conclude that somehow reciprocity is violated through this principle. The important fact is that the product in the frequency domain results in a convolution in the time domain and that the reciprocity relationship is no longer a simple one. Even though the transmit impulse response is the time derivative of the receive impulse response, reciprocity still holds! The above principle now helps us in characterizing different sensors for different applications as their temporal responses are quite different.

As a first example, it will be shown that an electrically large wide-angle biconical antenna on transmit does not distort the waveform, whereas on receive it does an integration of the waveform for certain conditions. In contrast, a TEM horn antenna on transmit differentiates the input waveform, whereas on receive it does not distort the waveform. Use of such transmit/receive antennas can actually produce channels with practically no dispersion. Experimental results covering GHz bandwidth signals will be provided to illustrate these methodologies. Examples regarding the impulse responses of other types of antennas, like the century bandwidth antenna, impulse radiating antenna, and the like will also be presented.