CHAPTER 6

CONCLUDING REMARKS AND FUTURE WORK

In this thesis, we have carried out a detailed study of various reconstruction schemes for generating finite energy localized wave pulses from dynamic aperture antennas. In addition, we have examined the propagation characteristics of LWs in dispersive media, the bistatic scattering of an acoustic MPS pulse from rigid and compressible spheres, and the properties of azimuthally polarized X electromagnetic waves.

In Chapter 2, we have discussed generation schemes for finite energy localized wave pulses resulting from finite time excitation and superposition of source-free FWMs. We have focused on the reconstruction of LW solutions of the scalar wave equation using Huygens' principle and the Rayleigh-Sommerfeld integral I and II representations, both in the time and frequency domain. Within the framework of these techniques, the sources are distributed in the form of annular sections over the aperture plane. These annular sections are driven with ultra-wideband signals having a time dependence that varies with the location of each driven element. We have confirmed the known fact that Huygens' construction filters out incoming (backward) acausal components of the aperture excitation fields; as a consequence, the generated fields are totally causal. Although this is not the case for the Rayleigh-Sommerfeld integral I and II representations, the acausal components can be significantly minimized by tweaking the parameters incorporated into the excitation wavefields $\left(\text{e.g., } \beta a_1 << 1 \text{ for the FWM and } pa_2 >> a_1 \text{ for the MPS}\right)$. Through the examination of the variation of the radiated wavefield for a specific range, we have established that there exists a minimum effective aperture radius for a satisfactory reconstruction; there is no need to go beyond this radius because the contributions to the field value are negligible. We have, also, addressed the diffraction length by analyzing the variation of the radiated wavefield with the longitudinal distance for a fixed radius of the circular array. We have confirmed the intuitive fact that the larger the radius of the array, the longer becomes the diffraction length.

Our work in Chapter 2 is confined to the reconstruction of four types of LW solutions of the scalar wave equation; specifically, the time-limited FWM, the time-limited zeroth-order and second derivative X waves and the MPS pulse. However, the techniques developed in that chapter can be used in the future for studying generation schemes and propagation characteristics (depletion of the spectral components, decay rates, time history, side lobes of the transverse variation, etc.) of other types of LWs resulting, for example, from the bidirectional representation or the newly developed boost variable representation.

After the detailed examination of various reconstructions schemes for scalar-valued LWs in Chapter 2, we have turned our attention to the study of two potential applications of LW pulses. The first deals with LW propagation in dispersive media and the second with the spherical scattering of an acoustic LW pulse.

In Chapter 3, we have undertaken a comprehensive study of the propagation of LWs in a collisionless plasma medium modeled by the Klein-Gordon equation. We have demonstrated that LWs generated by dynamic aperture antennas exhibit an unusual robustness as they propagate away from the aperture plane in a cold plasma. The slow decay rate is attributed to the extraordinary depletion of the spectral components of the radiated LW pulses. The coupling between the spatial and temporal frequency components controls the depletion of the spectral components. In our model, this coupling includes the source parameter k_s. If the latter is tuned to the plasma frequency k_p, effectively it places the windows scanning the spatial spectrum at higher values, thus reducing the depletion of the spectral components and decreasing the decay rate. Tuning k_s to the plasma frequency k_p requires *a priori* knowledge of the plasma frequency of the medium. For this reason, we have investigated the situation $k_s \neq k_p$ and have found that, except for small range values, the decay of LW pulses is as slow as in the tuned case.

In Chapter 4, we have examined the bistatic scattering of an acoustic MPS pulse from rigid and compressible spheres. A comparison has been made between the exact incident pulse and one reconstructed from a finite aperture in order to assess practical generation schemes using discrete annular sources (transducers). We have discussed the effect of variation of the scatterer material parameters on the amplitude of the spectrum in the ultrasonic acoustic regime. Our analysis has shown that extraction of the radius of a metallic sphere from backscattered data is feasible. Specific results have been obtained numerically for various types of soft spheres immersed in water. As the radius of the scatterer exceeds the waist of the ultra-wideband pulse, convergence difficulties arise because of the spherical Bessel and Hankel functions entering into the formalism. Application of Watson's transformation may alleviate these difficulties. A future objective is to change the medium surrounding the scattering in order to assess its effect on the spectrum. Another interesting goal is to adjust the parameters of the MPS pulse in order to extend its frequency band and adapt our analysis to ultra-wideband electromagnetic scattering problems.

In Chapter 5, we have initiated a study of vector-valued LWs. Specifically, we have presented a special class of infinite energy LW solutions to Maxwell's equations, which have been referred to as azimuthally polarized X waves. These solutions have been derived directly from Maxwell's equations without the intervention of potential functions. The reconstruction of finite energy (time-limited) versions of these LWs has been addressed using the vector-valued Kirchhoff surface integral representation, both in the time and frequency domain. The radiated fields have been determined from the knowledge of the tangential components of the electromagnetic field intensities on the aperture plane. The latter have been motivated from the structures of the source-free azimuthally polarized X waves.

The LW pulses considered in this thesis are compact in time and space and can propagate to large distances without significant dispersion. Furthermore, they can ameliorate channel effects, such as dispersion, and can exhibit unusual resolution capabilities in scattering experiments. For these reasons, they are desirable for many applications, e.g., directed energy transfer, secure communications, target identification, medical (ultrasonic) imaging, etc. Hopefully, recent advances in sources of ultra-wide bandwidth, such as opto-electronic switching technology and fast-responding piezoelectric transducers, will bring the implementation of LW pulses closer to reality.