ADVANCED CLASSIFICATION OF UXO USING FULLY POLARIMETRIC GPR AND FREQUENCY-POLARIZATION FEATURES

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1. ABSTRACT

The proper and accurate classification of buried UXO by remote sensor systems has been an important task due to the widespread clearance challenges presented by false alarms generated by clutter, shrapnel, and other environmental features. Despite the many improvements to sensor technologies in UXO applications over the years, false alarms continue to challenge proper UXO decontamination of sites worldwide. Ground penetrating Radar (GPR) technology has been applied to the UXO classification problem since the mid 1990s[1]. Classification algorithms using the complex natural resonance (CNR) signatures and polarization features, associated with the elongated body shape of most UXOs, have been developed to improve GPR classification performance. [1,2] Advanced classification algorithms using the spatial variation of the these polarization features, measured at multiple positions, have been developed in order to more accurately discriminate very shallow, non-UXO-like objects. [2,3] This approach provided different viewing angles of the subsurface target, allowing the more informed reconstruction of target geometry from signal variation. Recognition of the spatial variation of the target's polarization features reduced false alarms caused by shallow, offset, non-UXO items and also increased the detection rate of steeply inclined UXO items (i.e. vertical UXO). [4-6] However, some more complex, resonating clutter objects such as bent metal strips ("L" shapes or horseshoe shapes) and wire bundles produced strong resonance and polarization features when measured directly from above. Such clutter objects remained a major originator of false alarms. Discrimination of these objects is necessary to further improve classification performance. Therefore, in this paper, the scattering characteristics of such objects will be examined through numerical analysis. From the numerical study, it is found that these complex, resonating objects produce multiple resonances at differing frequencies and polarizations. Based on this observation, novel classification algorithms have been developed, which utilize the frequency-polarization dependent responses of complex targets to discriminate them from legitimate UXO. These classification algorithms were experimentally verified in a test bed environment, showing clear discrimination of such clutter objects. This paper will present observations from the numerical studies on the resonating clutters, novel classification algorithms using their frequency-polarization

dependency, and experimental results to verify the developed classification algorithms.

2. NUMERICAL STUDY AND CLASSIFICATOIN ALGORITHMS

When a conducting target is illuminated by broadband electromagnetic radiation, the incident fields induce currents that flow along the conducting surface of the target. When these currents reach the ends of a linear target strong diffraction occurs, reradiating energy while the remaining energy continues to flow back and forth between the two ends. This reverberation of surface current appears as a damped sinusoidal signal in the time domain and a resonant spectrum in the frequency domain. An elongated conducting object produces a strong resonance at a frequency whose half wavelength matches with the object's electrical length. [1] Thus, most UXOs, with their conducting and elongated bodies, produce a strong CNR. This CNR signature has been applied to UXO classification. [2] However, complex, resonating geometries ("L" shapes, horseshoe shapes, wire bundles, etc.) also produce a strong CNR. Figure 1 shows the simulated frequency domain response from a horseshoe shaped target. As one can see, this U shaped target produces multiple resonances, occurring in both polarizations - at 210 and 420 MHz parallel to the base of the U and 630 MHz parallel to the two arms. The scattering characteristics of these geometries are different from that of UXOs, in that a UXO produces only one CNR in a polarization parallel with UXO's long axis. Consequently, this frequency-polarization dependent response of targets of complex shapes can be used to discriminate them from UXOs by applying a frequency sub-banding method.

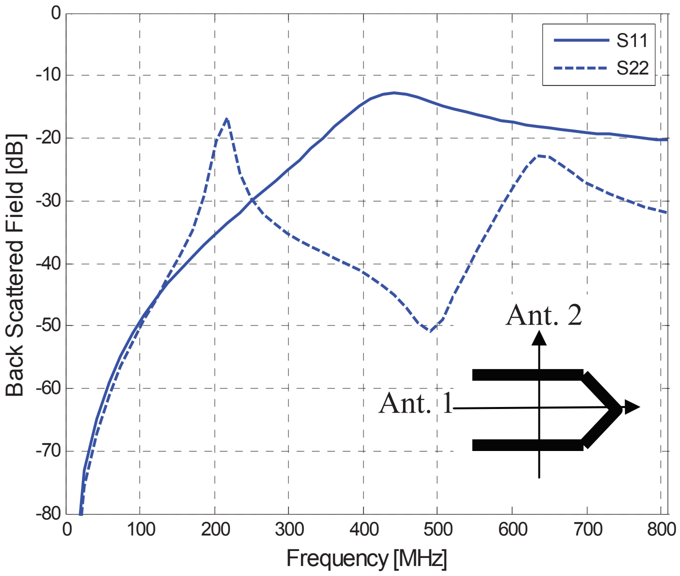


Figure 1: Frequency-domain response from a horseshoe shaped target.

3. EXPERIMENTAL RESULTS

Figures 2 and 3 show experimental measurement data illustrating the frequency-polarization dependency of a horizontal, horseshoe shaped object in the frequency and time domains, respectively. This geometry possesses resonance features in both polarizations and often causes false alarms in detection. As one can see in Figure 2, the U shaped target produces two different resonance frequencies (parallel and perpendicular to the base of the U). After applying band-pass filtering on the frequency domain responses for the two orthogonal polarizations and converting it into time domain using an IFFT, a strong S_{22} response can be observed in the lower frequency sub-band (Figure 3b) while the higher band (Figure 3c) shows a dominant S_{11} response.

The occurrence and location of these signals, in both the time and polarization space, are directly dependent on the geometry of the complex target. The scattering images in different polarizations, viewed in several sub-bands, thus provide a target fingerprint. Whether or not this fingerprint is unique to a single geometry, it is significant indication that the target in view is not the more simplistic scattering from a UXO. It is proposed that this data set can be additional tool and classification parameter for target discrimination in UXO applications. It is worth noting that the sub-band approach involves the tradeoff between two considerations: narrower sub-bands provide more detailed frequency dependency information, while wider sub-bands provide better spatial resolution.

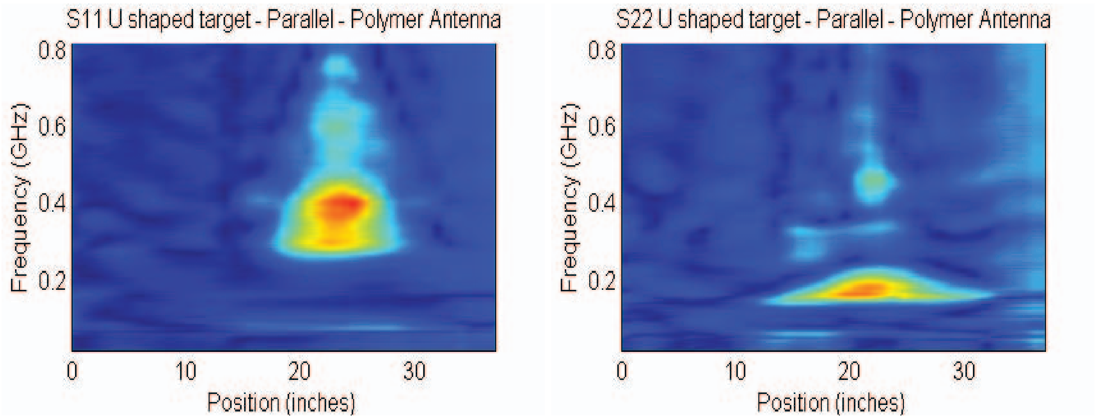
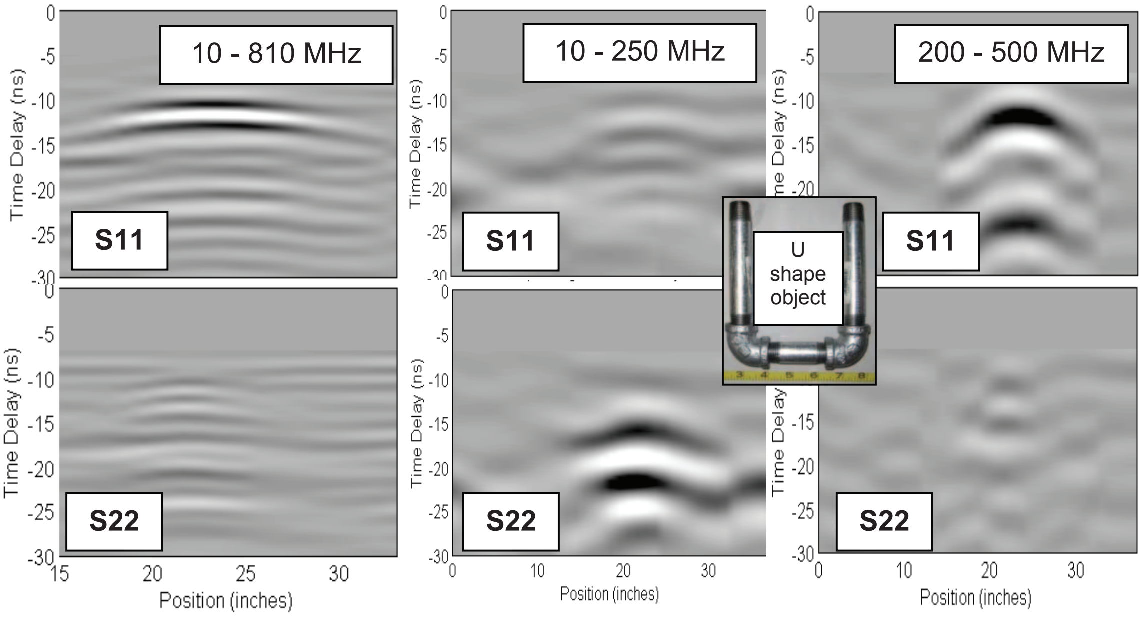


Figure 2: Measurement result of Frequency-domain scattering response of a horizontal horseshoe shape object.



(a) Full-band (b) Sub-band 1 (c) Sub-band 2

Figure 3: Measured fully-polarimetric data of a horizontal horseshoe-shaped target shows the frequency-polarization dependency in time-domain sub-band plot.

4. REFERENCES

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