Reduction of Radar Cross Section Using Active Microstrip Antenna Elements

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***Abstract*—The scattering from an object can be reduced by using active microstrip antenna elements to cancel the scattering from the object. Sensors are placed on the object to sample the local field at the surface of the object. This information is then used to adjust the radiation from the antennas in order to cancel the scattering from the object.**

Keywords—radar cross section, microstrip antenna; scattering cancellation

I. Introduction

The reduction of electromagnetic scattering by an object is a challenging area with applications in both military and commercial systems. Areas of military applications include stealth technology and the protection of personnel and assets. Commercial applications include the reduction of electromagnetic interference (EMI) arising from radar installations operating near civilian facilities. The general goal of the research here is to minimize the radar cross-section (RCS) [1] of an object (aircraft, missile, building, etc.) by using an array of radiating antennas on the surface of the object. In the case of a monostatic radar the source and receiver are at the same location, and only a single antenna on the object is required, in order to eliminate the scattered signal for a given polarization. This is the case studied here, though the approach can be generalized to the bistatic situation.

In the present approach, a sensor is placed on the surface of the object to probe the total field that is set up on the surface of the object by the incoming plane wave. The voltage measured by the sensor is then fed into the radiating antenna through a circuit containing an amplifier and phase shifter in order to produce the desired radiation from the antenna that will cancel the natural scattering from the object back at the radar receiver. The connecting circuit between the sensor and the antenna is designed to keep the time delay as low as possible. Here we have used a microstrip antenna [2]-[3] as the radiating element. The approach is thus different from cloaking, which makes use of active sources or surfaces to conceal an entire object from an interrogating signal [4]-[5].

II. Proposed Design

We consider one microstrip patch antenna mounted on the surface of the object, located near a sensor. The time-harmonic voltage measured at the terminal of the sensor due to the incident plane wave impinging on the object is multiplied by an appropriate complex weight (i.e., a specific gain and phase shift) and this weighted voltage is applied to the patch antenna. The complex weight associated with the sensor is pre-determined to effect scattering cancellation for a given polarization and angle of incidence. Eliminating both possible polarizations requires at least two sensors and two antennas. The scattering reduction concept is illustrated here for a single polarization, which requires only one sensor and one patch. One possible sensor is a vertical coaxial probe with two horizontal branches, as shown in Fig. 1.

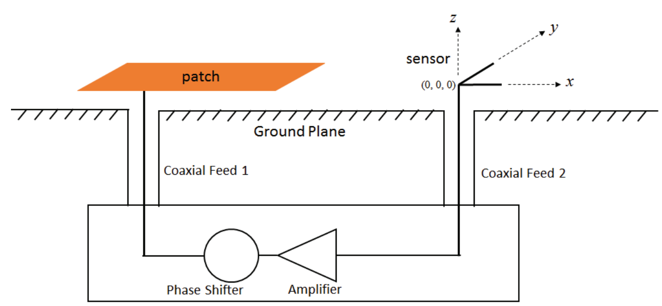

Fig. 1. Geometry of the patch and sensor on the object (shown as a finite ground plane), together with the amplifier and phase shifter circuit.

The voltage signal from the sensor is fed through an amplifier and phase shifter into the patch antenna. A delay line (e.g., a microstrip line) is assumed to exist between the sensor and the amplifier/phase-shifter circuit, to account for practical connecting circuitry. Note that this system, when designed properly (i.e., with a proper choice of amplifier gain and phase shift), will eliminate the monostatic scattering from the object in the polarization of interest, at the design frequency (which is also the frequency of the patch resonance). It is not clear how well the scattered signal will be reduced for a time-varying incident wave, corresponding to a practical radar signal, and this is the subject of the investigation here.

III. Analysis

For the purpose of the analysis, we have assumed that there is a fixed constant of proportionality between the voltage at the patch feed and the sensor output voltage, which is predetermined to allow for a complete cancellation of scattering at the center frequency of operation. For the initial analysis the output impedance of the amplifier is taken to be zero (an ideal amplifier) in order to simplify the calculations.

The input impedance of the patch is modeled using a simple CAD formula for simplicity [2]. The frequency-domain scattered signal is then calculated at any given frequency. The inverse Fourier transform is then used to calculate the time-domain scattered signal from a given time-domain incident plane wave. Further details are omitted here.

IV. Preliminary Results

Consider a radar signal which is a chirp-modulated rectangular pulse with a 2% chirp bandwidth and a center frequency of f_0 = 1.575 GHz (chosen arbitrarily to demonstrate the concept). The plane wave is incident from broadside in Fig. 1. The time-domain normalized incident electric field from the radar with polarization in the *x*-direction is shown in Fig. 2. Here the width of the pulse T_p is taken to be 500 times the period of the carrier i.e. $T_p = 500/f_0$. The scattered field from the object in the presence of the optimized patch/sensor system shown in Fig. 1 is calculated in the time domain, and the scattered signal is presented in Figs. 3-5 for different lengths of the delay line, corresponding to 0, 1 and 5 wavelengths at the center frequency f_0, respectively. The incident field exists in the time region between -0.15 and 0.15 μs (a total duration of 0.30 μs).

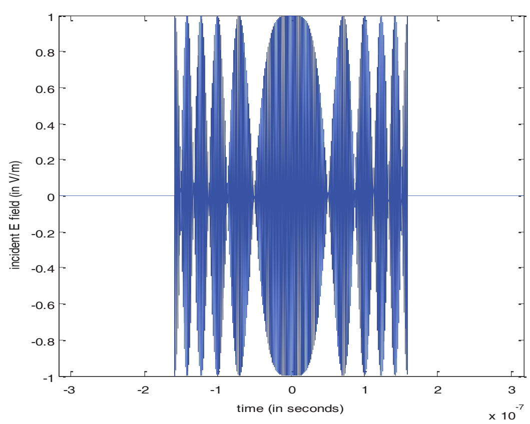

Fig. 2. Incident electric field on the object as a function of time.

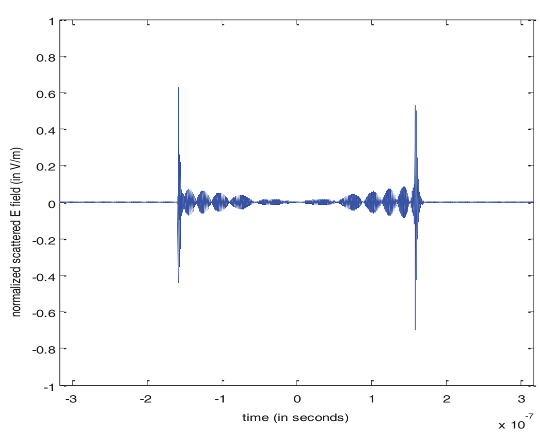

Fig. 3. Scattered field when the effective length of the delay in the circuits is zero.

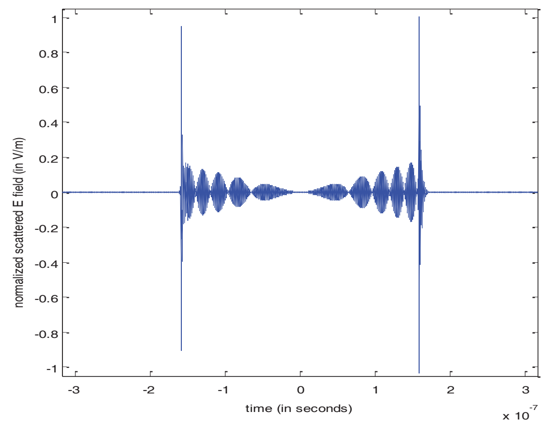

Fig. 4. Scattered field when the effective length of the delay in the circuit is 1 wavelength.

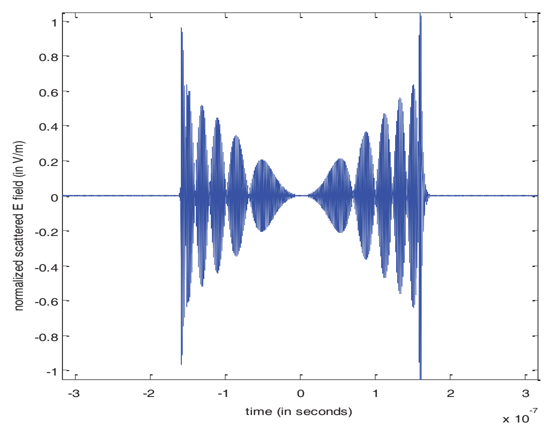

Fig. 5. Scattered field when the effective length of the delay in the circuit is 5 wavelengths.

V. Conclusions

The results in Figs. 3-5 show that the maximum amplitude of the scattered signal is not significantly reduced, but the time duration of the scattered signal (and thus the energy in the scattered signal) is. This could be important since low-energy scattered pulses may be difficult to detect be a receive radar. The results in Figs. 3-5 also show that the energy in the scattered signal is minimized by minimizing the delay in the circuitry. Furthermore, it is seen that most of the scattered signal is concentrated near the edges of the pulse.

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