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Computer Simulation to Assess Effects of Aircraft Structures on Flight Inspection Antenna Performance

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ABSTRACT

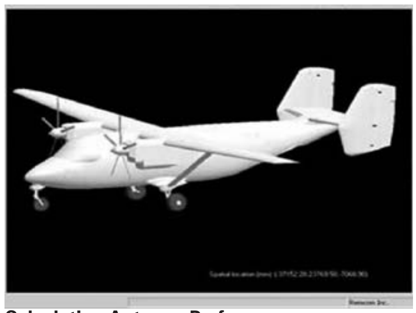
This paper describes the results of a computer simulation effort undertaken to investigate the effects of aircraft struc-tures on flight inspection antenna per-formance. Under normal circumstances the flight inspection mission places de-manding requirements on aircraft antenna performance, but meeting those require-ments for the application described here was particularly challenging because of the unusual airframe structure of the air-craft selected. The Polish Air Force de-sired to use a Mielec M-28, such as the one pictured below, for flight inspection.

The dual-vertical stabilizers of the M-28 presented an unusual configuration for a flight inspection aircraft, and the effect of this type of empennage on VHF navigation antenna performance was unknown.
To determine how this aircraft would perform as a flight inspection platform, the electromagnetic performance of the antennas mounted on the aircraft was simulated using full-wave electromag-netic analysis software based on the Fi-nite-Difference Time-Domain (FDTD) technique. VOR/LOC antenna perform-ance was calculated for various antenna types and installation locations in order to determine the optimum configuration which would satisfy the flight inspection mission requirements. This paper de-scribes the simulation process, beginning with the importing of aircraft CAD files and concluding with 3-dimensional plots of the resultant far-field antenna pat-terns. The FDTD software used in this work provides a wide range of graphical outputs that can provide insights into how electromagnetic waves interact with various structures, and is very useful for analyzing and solving many different types of real-world electromagnetic problems.

IMPORTING AND EDITING THE M-28 AIRCRAFT MODEL

The M-28 analysis started with a CAD file that was provided by the aircraft manufacturer. The CAD file included most of the aircraft geometry. This par-ticular CAD model of the M28 contains 10,827 objects in a file about 150 Mbytes in size.
XFDTD imported this file in about 3 minutes. The result is shown in the fol-lowing figure.

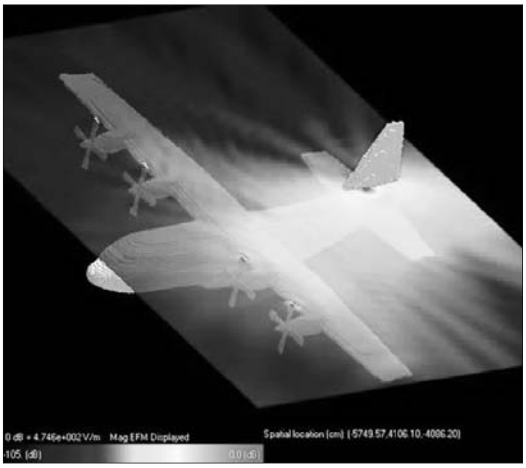
After importing the M28 geometry into XFDTD, it became clear the CAD file supplied did not describe the complete aircraft. The model lacked a rear hatch and the engines and propellers were ab-sent Using XFDTD geometric primitives and Boolean operations, the missing components were added to the aircraft.
Based on drawings of the engines, CAD models of the engines were created using the XFDTD geometrical modeler. First a single engine model was created and saved as a CAD file in SAT format. The SAT engine model was then imported back into XFDTD.
The engine geometry was imported twice and positioned on each wing. Also, the tires were changed to a non-conductive dielectric approximating rubber. The completed model is shown below. Now all that remains is to add antennas to the model and run the XFDTD simulations.



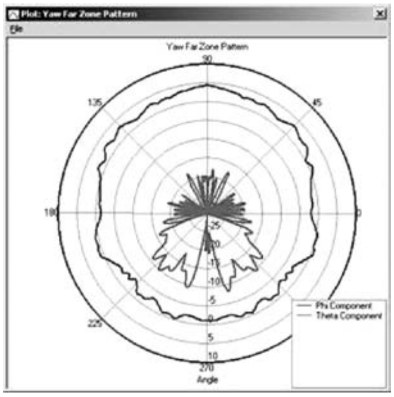
Calculating Antenna Performance

CALCULATING ANTENNA PERFORMANCE

Once the aircraft model was ready the M-28 analysis continued with placement of antennas on the aircraft. The study involved two different antenna types, a balanced half-loop antenna called a 'towel bar' and a bent dipole V-shaped antenna. The half-loop antennas are in-stalled in pairs on each side of the air-craft and phased to provide symmetrical antenna patterns when fed together. The bent dipole antenna is located on top of fuselage on the aircraft centerline.
The initial phase of the analysis involved placing these antennas at various loca-tions on the aircraft and calculating the far zone 2D and 3D antenna patterns. From the results of these calculations candidate antenna types and positions were chosen. Then, for these candidate positions XFDTD was used to investi-gate position sensitivity and frequency sensitivity in order to determine how ro-bust the candidate design would be in the field. Aircraft skin currents were also calculated and displayed to indicate the interactions of the aircraft, especially the large vertical stabilizers, with the an-tenna radiation.
As with the aircraft engines, the XFDTD geometric modeler was used to generate the half-loop and bent dipole antenna geometries. These were then exported to CAD files, then imported and positioned on the XFDTD aircraft model for calcu-lation.
As a baseline comparison a few calcula-tions were made for a C-130 aircraft. This aircraft has a single vertical stabi-lizer and poses no difficulties in provid-ing the desired omni-directional azimuth pattern. As with the M-28, a CAD model of a C-130 was obtained and imported into XFDTD. A half-loop antenna was located on the vertical stabilizer and azimuth plane antenna radiation patterns were calculated using XFDTD. The fol-lowing figure shows the electric field in the plane of the antenna.



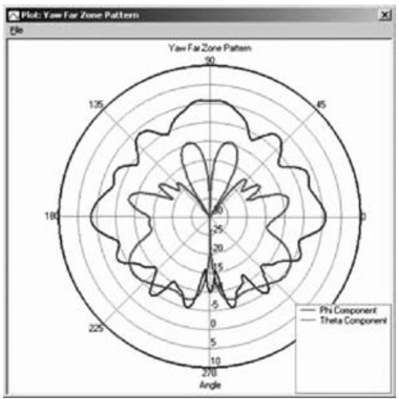
The figures below show the modeled azimuth plane radiation pattern for the C-130. Notice the very uniform coverage for the Phi (horizontal) polarization, which is of primary importance for flight inspection operations. This is an ex-pected result given the symmetry of the aircraft empennage.



The angle Phi is referenced to the posi-tive x-axis as depicted below.

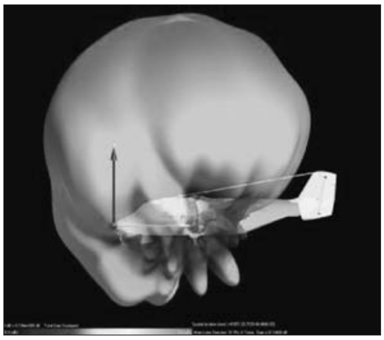
Next are shown a few selected results from the M-28 aircraft study. The first configuration is a pair of balanced loop antennas located on the rear fuselage of the M-28 aircraft. The aircraft skin cur-rents are shown in the following figure.

The pair of figures below shows the azimuth plane radiation pattern for this antenna configuration. The performance is not acceptable due to the variations in gain, especially in the forward direction.

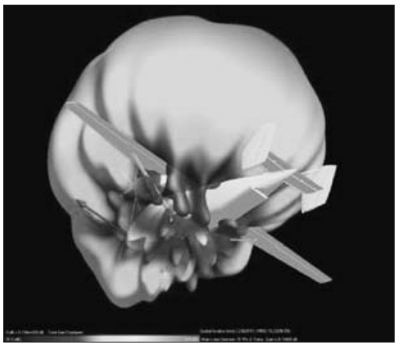


Several other positions for balanced loop antennas were tried, but none gave an acceptable radiation pattern over the en-tire azimuth plane. A midship location was also unable to provide the desired uniform pattern. Other positions for balanced loop an-tenna locations, including on the vertical stabilizers, were tried but without pro-viding a uniform azimuth plane pattern. Next a bent dipole antenna was placed at the top of the fuselage. That antenna configuration provided excellent cover-age forward but poor coverage to the side and rear.

In addition to the azimuth plane antenna pattern plots XFDTD provided 3D pat-terns as well. These give a more general view of the radiation from the various antennas. The following figures show the 3D antenna pattern for the bent di-pole antenna for different views. The first view is in the YZ vertical plane.



This second view is from the bottom of the aircraft.



Only a few of the many results provided by XFDTD for this study are shown here, but enough to indicate the final so-lution. Airfield Technology installed both the bent dipole and rear-fuselage balanced loop antennas in a switched configuration. The bent dipole is used when the aircraft is flying toward the air navigation system, and the balanced loop used for outbound patterns and during orbital type flight patterns when the air-craft flies in an arc around the air navi-gation system. Airfield Technology con-figured the airborne equipment so that the flight inspection system computer automatically selects the correct antenna for the type of pattern being flown.

XFDTD allowed potential problems with the antenna performance to be identified and solved prior to installing the actual antennas on the aircraft, ultimately sav-ing the customer significant time and money.