SWEEPEM

by T.G.T. Bremner

In the summer of 1984, Kenting began field trials of a new airborne electromagnetic system called SWEEPEM. The ability for deep penetration and accurate overburden resistance mapping will remain useful through the eighties and beyond.

SWEEPEM is somewhere between the humble metal detector that finds pennies on the beach and a radar installation that can be tuned to a single snowflake over the Gatineau Hills or an ICBM launch in Siberia.

SWEEPEM transmits a powerful multi-frequency signal from a large loop installed around the survey aircraft. The signal is reflected from geological features and detected in a bird towed one hundred meters behind the aircraft. Fibre optic lines in the tow cable send the reflected signal to a computer in the aircraft. The computer exchanges about one hundred thousand numbers per second with a transmitter and the bird. These data are processed in real time, reduced to manageable proportions, presented to the operator and stored for later interpretation.

Kenting has installed this system in a CANSO aircraft. Shell Research Laboratory in Den Haag, Holland, designed and built the system. The Shell laboratories, in the forefront of seismic prospecting research, routinely use the most sophisticated methods of acquisition, analysis and presentation of survey data. Kenting has many years of experience in flying EM surveys with the CANSO aircraft. The low cruising speed, long range and low level flight capability of this aircraft will map large survey areas with impressive spatial resolution. The collaboration between Shell and Kenting ensures that SWEEPEM incorporates the most modern techniques in data acquisition and processing, and that reliable economic operation in the field will be achieved.

The first requirement of an EM system is raw power. The huge 30 metre wingspan of the CANSO, and the transmission of over 300 amps through the cable looped around the aircraft, generates a powerful magnetic dipole. When the transmitter goes on, every CRT and video display in the CANSO flinches. An airborne system is over a target for only a brief moment. Thus, performance depends less on peak power and more on how much energy can be injected into a target while it is within range. There exist other systems with equivalent peak power, but none can match SWEEPEM's average dipole of 10^5 Am^2 rms. The 100% duty cycle and fast rise time of the SWEEPEM computer controlled transmitter ensures the average power is close to the peak power. The exact moment of transmitter switching is controlled and, by using a complex waveform first used in radar applications, the ground response is determined without switching off the transmitter. The 300 amp current in the cable is never off. When the transmitter switches, the current polarity is reversed within 100 μsecs.

The power can be divided among as many, or as few frequencies as required within the broad bandwidth of the system; presently 100Hz to 5KHz. This will be useful for more complex jobs such as resistivity mapping.

In the winter of 83/84 Kenting and Shell cooperated on installing the transmitter in the CANSO. The power requirements demanded an extensive rewiring of the aircraft. There were some initial problems due to the thousand volt spikes that occur when switching 300 amps in a few microseconds. (Those who work with the puny 5V of TTL circuits don't know what they are missing.) In any case, by the summer of 1984 test flights could begin.

The second requirement of an EM system is sensitivity. The receivers in the bird have more than enough sensitivity; they were designed to measure the earth's magnetic field from an altitude the CANSO cannot reach – an ESA satellite. They cannot, however, measure a field greater than 5 gamma. Even where the bird flies at the end of 100 metres of cable, the primary field is about 10 gamma. Sensitivity is a challenge around such a powerful transmitter. The receivers are useless if they are constantly saturated by the primary field. The primary field, which is constant to a first approximation, must therefore be removed. On an early test flight the computer generated a bucking waveform which tracks the rapid rise-time of the transmitter. A one megahertz digital signal carries the bucking waveform to the receivers through a fibre optic in the tow cable.

An EM system must also be accurate, which is partly a matter of hardware design. For example, the use of fibre optics for all communications with the bird electrically isolates the bird from the aircraft. The strong EM fields generate large secondary currents in a metal tow cable which is a source of inaccuracies in previous systems. SWEEPEM utilizes a Kevlar tow cable incorporating fibre optics communications. Accuracy is also greatly improved by the powerful computer on the aircraft. The computer handles timing, data acquisition, reduction and storage tasks, but also has the capacity to do much real time signal processing.

The accurate data gathered by an EM system should also be comprehensive. Earlier systems did not provide a towed bird, or did not provide in-phase data. SWEEPEM is a towed bird in-phase system and combines the advantages of both these early approaches to EM prospecting. The in-phase response is important for the analysis of conductive structures. For instance, the response of conductive overburden can swamp the out-of-phase data. No previous in-phase towed bird system has been successful due to the catastrophic effects of bird swing. This is unfortunate since the favourable geometry of a towed bird boosts sensitivity. Shell, therefore, developed a unique real time bird motion correction algorithm. The test flights have shown this algorithm works very well, providing equivalent noise levels in both in-phase and out-of phase.

Finally, the data must be presented in a form that people can understand. Older systems were categorized into time and frequency domain systems. SWEEPEM blurs this distinction. The transmitter works in the range of 100Hz to 5KHz, but data are acquired in the time domain. The computer converts the data into the frequency domain for much of the signal processing, then can convert it back into the time domain. In fact SWEEPEM will provide, on demand, time or frequency data. Nevertheless, interpretation of dual receiver, dual phase, multi-frequency data will be a challenge. Shell, drawing on its experience with complex seismic results, has prepared a package based on the one layer overburden model. The output might be used directly for resisitivity mapping. The statistical output shows where the model does not fit and quickly locates and flags anomalous regions. Thus the full potential of the SWEEPEM data will be realized.

The initial test flights in 1984 have shown the great potential of SWEEPEM. Kenting expects to be able to offer its customers a uniquely powerful and sophisticated airborne EM system which will have the capability to perform the new and complex jobs of the coming years. K