*11th SAGA Biennial Technical Meeting and Exhibition*
*Swaziland, 16 - 18 September 2009, pages 131 - 133*

# Can the Spectrem Transmitter and Processing Work on a Small Helicopter Platform?

**John Bell[1]**, Braam du Plooy[2]

1. AngloGold Ashanti, South Africa, jbell@anglogoldashanti.com
2. Spectrem Air Limited, South Africa, braam@spectrem.co.za

## ABSTRACT

The Spectrem waveform and processing has many advantages. The possibility of implementing this on a central-loop helicopter platform was investigated. Data was acquired in early 2008 with ground and flight tests.

The amplitude of the anomalies produced by the Step Response processing are modulated by the amount of primary field present at the receiver. The smaller the primary field (larger "Bucking Factor"), the larger the anomaly amplitudes, however this makes the system more sensitive to geometric changes.

The ground and flight tests suggest that the Spectrem waveform and processing is not suitable for a central loop helicopter system due to it's sensitivity to geometric changes.

**Key words:** airborne electromagnetics, Spectrem, central loop system, bucking

## INTRODUCTION

Why the Spectrem system? The Spectrem fixed wing system utilizes a 100 percent duty cycle transmitter. The system response is removed by means of a reference and calculation of the Step Response by means of convolution. This has many advantages which include removal of the system response, calibration, and conductor discrimination. In addition, the real time processing and interpretation algorithms developed at Spectrem Air can be applied directly to helicopter data.

An on-time transmitter, similar to that utilized by the Spectrem2000 system, was developed and tested in a central loop system (AeroTEM II). On this platform, partial cancellation of the primary field at the receiver is required for dynamic range reasons. Various ground tests were performed, followed by a flight test over a ground loop.

The Spectrem system (which includes a transmitter current shape and processing algorithm) is sensitive to geometry. This makes it inappropriate in a central loop system where bucking of the primary field is required.

## REDUCING THE PRIMARY FIELD AT THE RECEIVER

The response from the earth (secondary field) is usually orders of magnitude smaller than the primary field. The receiver system must be sensitive enough to measure small signals associated with the secondary field, and at the same time it must have the dynamic range to measure the primary field. This requirement is valid even for most off-time systems, since the receiver is never "switched off". Bucking is the technique of reducing the primary field, without changing the transmitter dipole moment, so the secondary field becomes a relatively larger fraction of the primary field. The bucking of the primary field is brought about by establishing an additional primary field that opposes the field from the transmitter in such a manner that the two fields closely cancel each other at the position of the receiver.

## THE EFFECT OF GEOMETRICAL CHANGES ON THE OBSERVED PRIMARY FIELD

The standard Spectrem processing yields the following result (in the frequency domain):

$$\frac{B^s}{G_r} + \frac{G}{G_r} \tag{1}$$

where:

$B^s$ is the secondary field (target response);

$G$ and $G_r$ is the (geometrical factor of) the primary field at the time of measurement and of the reference signal, respectively.

Expression (1) is convolved with a square function and the result is referred to as the “Step Response”. This has units of ppm of the primary field. In the case of a central loop system, the primary field refers to a bucked field.

The bucking effect is controlled by the relative geometry of the transmitter loop, bucking coil and receiver coils. Because of the non-rigid construction of the EM bird, it is possible that changes in the effective bucking could occur, with a resultant change in the measurement as expressed by Equation 1.

In Equation 1, $G_r$ is the geometric factor that was effectively collected (and stacked) during the reference flight. For our purposes this is a constant. Hence we only need to consider changes in the value of the geometric factor $G$ to investigate its effect.

In order to study the dependence of the bucking on geometrical changes, we use a simplified model of the bucking system namely a system in which the three coils (transmitter loop, bucking coil and z-receiver coil) are perfectly coaxial. The transmitter loop and bucking coil are coplanar.

The formula for the geometric factor in this case is

$$G = \frac{\mu a^2 N_T}{2(z^2 + a^2)^{3/2}} - \frac{\mu b^2 N_B}{2(z^2 + b^2)^{3/2}} \qquad (2)$$

$a$ and $b$ is the radius of the transmitter and bucking coil respectively.

$z$ is the height of the receiver above the plane of the transmitter...

$N_T$ and $N_B$ is the number of turns on the transmitter and bucking coil respectively.

The only motion that is allowed in this model is a vertical displacement of the receiver coil. When the z-receiver is in the plane of the transmitter loop, the condition for the primary field to be exactly zero (perfect bucking) can be derived from Equation 2:

$$\frac{N_T}{a} = \frac{N_B}{b} .$$

The x- and y-coil of the receiver are uncoupled i.e. the x- and y-component of the primary field are zero.

The relative change in the geometric factor depends (quite sensitively) on the value of $G_r$.

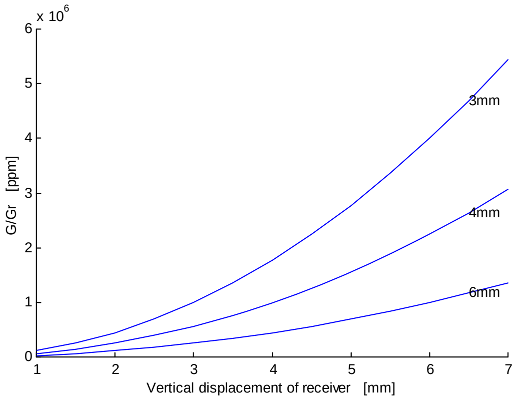

**Figure 1. The geometric factor ratio (primary field) versus vertical displacement of the receiver coil. The labels on the different curves are the vertical off-sets of the receiver during the reference measurement.**

Figure 1 illustrates the change of the primary field as a function of receiver position. Note that $G/G_r$ is the offset of the Step Response and is often referred to as the primary field. So if $G = G_r$ then the primary field of the Step Response is 1000 000 ppm. It is evident that the closer the receiver is to the plane of the transmitter and bucking loop during the reference, the more sensitive the geometric factor is to vertical displacement of the receiver. This would seem to imply that some initial vertical displacement of the receiver is required to reduce the sensitivity to vertical displacement (i.e. increase the size of the primary field at the receiver).

## GROUND TEST

A ground test was carried out in January 2008 with the AeroTEM platform utilizing the Spectrem waveform. A conductor (L=1.292 mH, R=1.15 Ω) was dragged past the platform at a distance of 4 metres from the centre line of the EM platform. The transmitter frequency was 125 Hz and the current amplitude 42.5 A. The channel times are given in Table 1.

| Channel No | Mid-Time (ms) |
|---|---|
| 1 | 0.0156 |
| 2 | 0.0313 |
| 3 | 0.0625 |
| 4 | 0.125 |
| 5 | 0.25 |
| 6 | 0.5 |
| 7 | 1 |
| 8 | 2 |

Table 1. Channel Times (ms)

The bucking factor was determined by measuring the peak amplitude at the receiver coil with the bucking coil both connected and disconnected, and taking the ratio:

$$\text{Bucking Factor} = \frac{Primary\_Voltage}{Bucked\_Voltage}$$

Hence, a large Bucking Factor denotes a small primary field at the receiver. Two test were carried out with a Bucking Factor of 1155 and 10734, respectively (Figures 2 and 3).

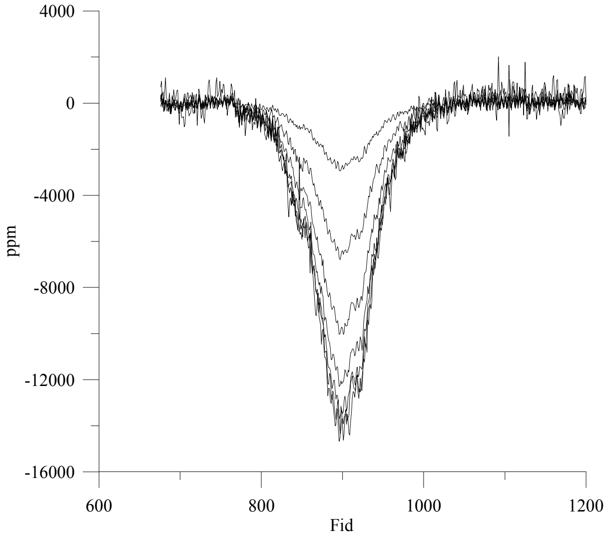

**Figure 2. Ground Test Data (Z-Component) with a Bucking Factor of 1155.**

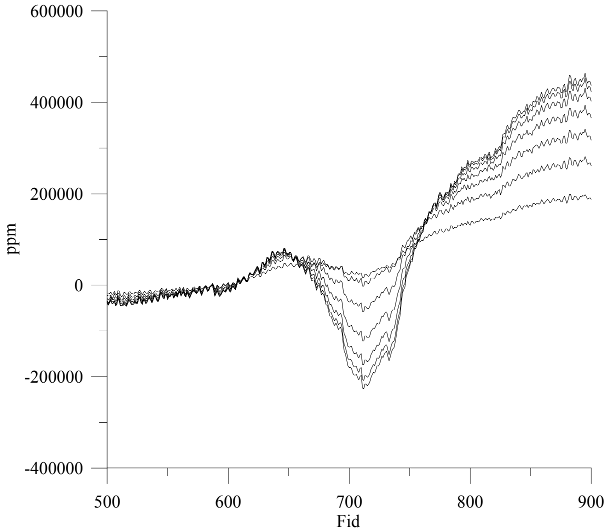

**Figure 3. Ground Test Data (Z-Component) with a Bucking Factor of 10734.**

Note the difference in anomaly amplitudes between the two tests. This is due to the difference in primary field strength at the receiver. The data with a larger Bucking Factor (Figure 3) has excessive drift but larger anomaly amplitudes. The drift is interpreted to arise from thermal distortion of the frame. Clearly this noise would increase significantly during flight. A practical consideration therefore is the trade-off between the anomaly amplitudes and the amount of geometric noise permissible.

## FLIGHT TEST

In March 2008 data was acquired over a square ground loop with a side length of 80 m. The time constant of the ground loop was 0.54 ms and was measured using a RCL meter. The transmitter was approximately 50 m above the level of the ground loop. Figure 4 illustrates the results.

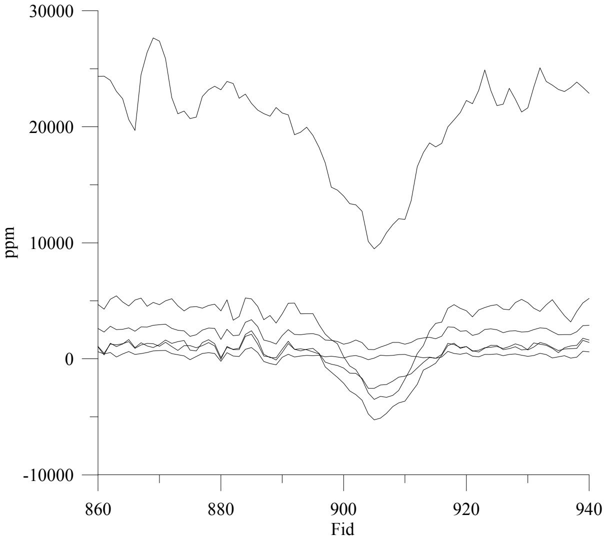

**Figure 4. Measured Z-component data across the ground loop (height=50 m).**

The ground loop response is poorly defined and the data has a poor signal to noise ratio. The Bucking Factor has been set to minimise the drift but the flight data still displays significant noise.

## CONCLUSIONS

The sensitivity of the primary field at the receiver to geometric changes makes the in-loop helicopter platform unsuitable for the Spectrem transmitter waveform and deconvolution processing.

In order to overcome this limitation it is necessary to move the receiver away from the transmitter, as was implemented in the ExploreHEM system.

## ACKNOWLEDGMENTS

Spectrem Air Limited and AngloGold Ashanti are thanked for the opportunity to present these results.