Office Action Response

This office action tries to equate the non-linear sampling technique described in the Muhlenberg patent (US 5,836,982) with the *compressed sensing* technique that is utilized in the Mittal patent. If those two techniques can be shown to be equal then, as this office action asserts, a simple combination of Mahajan plus Muhlenberg would render the Mittal patent obvious to one of ordinary skill in the art. Therefore in this response we will strive to clearly show how these two techniques are vastly different and hence the Mittal patent should be allowed.

We begin with an arguably obvious point which is that there is a 11-year gap between the time that Muhlenberg (February 1997) discloses his non-linear sampling technique and the first emergence of the revolutionary compressed sensing technique as described in the seminal IEEE paper *"An Introduction to Compressive Sampling,"* (March, 2008) referenced in the Mittal patent.

Beyond this obvious, difference, and while both approaches center around skipping samples in order to achieve efficiency in signal processing, there are a number of substantive technical differences between the two approaches which are outlined below:

Muhlenberg's technique relies on the generation and use of a companion "threshold signal" (In Fig 6A block 95, the output from the threshold signal generator block 94 is compared against the input physiological signal to accept or reject it. Fig 6B shows both "signal input" and "threshold"). In fact, this is how Muhlenberg is able to achieve his goal of non-linear sampling (or sample skipping), which in turn leads to a reduction in the number of samples needed to faithfully reproduce the original physiological signal (e.g. EKG). This reduction in required samples leads to the ultimate benefit of Muhlenberg's technique; less power used by the implantable device. The threshold signal "from generator 94 is essentially a time varying threshold signal" (Muhlenberg, col 7, lines 52-55), "is relation to a varying input signal" (Muhlenberg, col 8, lines 5-12),"the shape and timeout" of the signal is a "matter of design choice" (Muhlenberg, col 8, lines 46-47) and can be varied "either by programming or by adjustment based on accumulated data" (Muhlenberg, col 9, lines 11-14). In other words, the use of a threshold signal is what ultimately determines how good a result Muhlenberg's technique will deliver. Muhlenberg does not disclose or suggest any *compressed sensing* analog-to-digital conversion (CS-ADC) as taught by Mittal, but relies upon measurement of the degree of variation of the input signal via a threshold to determine acceptance or rejection of the acquired sample for subsequent ADC (Muhlenberg, independent claims 1, 4, 9, 12).

The **Mittal** patent and the compressed sensing technique in general does not rely on any type of self-generated, companion threshold signal or determination of variation for efficacy, but rather relies on inherent properties of the analog input signal, namely "sparsity" and "incoherence". A detailed explanation of these two characteristics and their relevance to compressed sensing can be found on pages 22-

23 of the IEEE paper *"An Introduction to Compressive Sampling"*. "Sparsity: Many natural signals have concise representations when expressed in a convenient basis. Most coefficients are small and the relatively few large coefficients capture most of the information." (IEEE Signal Processing Magazine March 2008, page 23, See Fig 1(b)). "Coherence measures the largest correlation between any two elements of the sensing basis and the representation basis. CS is mainly concerned with low coherence pairs." (IEEE Signal Processing Magazine March 2008, page 23). In order for compressed sensing to work, the input signal must be both sparse and incoherent. The Muhlenberg technique doesn't rely on either of these characteristics but instead relies on actual analysis of the input signal by comparing to a companion "threshold signal" to determine when to sample the signal and when not to. This analysis requires the technique to comprehend or be aware of the subtleties of the input signal. By contrast with CS: "The crucial observation is that one can design efficient sensing or sampling protocols that capture the useful information content embedded in a <u>sparse signal</u> and condense it into a small amount of data. These protocols are nonadaptive and simply require correlating the signal with a small number of fixed waveforms that are <u>incoherent</u> with the sparsifying basis. What is most remarkable about these sampling protocols is that they allow a sensor to very efficiently capture the information in a sparse signal <u>without</u> trying to comprehend that signal… In other words, CS is a very simple and efficient signal acquisition protocol which samples – <u>in a signal independent fashion</u> – at a low rate and later uses computational power for reconstruction from what appears to be an incomplete set of measurements." (IEEE Signal Processing Magazine March 2008, page 22). "CS operates very differently, and performs as if it were possible to directly acquire just the important information about the object of interest" (IEEE Signal Processing Magazine March 2008, page 28).