IntriCon

Technology White Paper

Performance of the Automatic Directional Processing

New technology used in the inTune™
DSP amplifier from IntriCon.

(with information on input selector adjustment)

October 10, 2005

inTune™

Automatic Directionality Algorithm Description

The inTune amplifier has the feature of automatically switching between omni microphone input and directional microphone input. This feature is designed to smoothly switch to the directional mode when there are strong sound inputs from the side and rear. When the sound source is primarily from the front, the amplifier switches back to the omni mode. This feature allows, for example, hearing aids to benefit from directional microphone performance in noisy situations while providing omni input during quiet listening environments. We refer to this feature as auto-direct.

The auto-direct feature works with hearing aids built with two omni microphones that have ports located 5 mm to 14 mm apart. The ports need to be aligned so that the line connecting the rear mic to the front mic is approximately horizontal and points to the front. This is the same requirement of a fixed directional mic system that is constructed with two omni mics.

The automatic feature works by estimating the conditions where directionality would provide benefit. Figure 1 shows the decision process. The algorithm forms two main calculations that are the start of this process. The first calculation is the power from the directional mic (referred to as "FRONT" in the flow chart). This is formed by delaying the rear mic appropriately and subtracting it from the front mic The second calculation is the power in the "OMNI" mic. For this calculation, the output of the front mic is first filtered to match the low frequency roll-off inherent in the directional mic. The power of this filtered output is calculated.

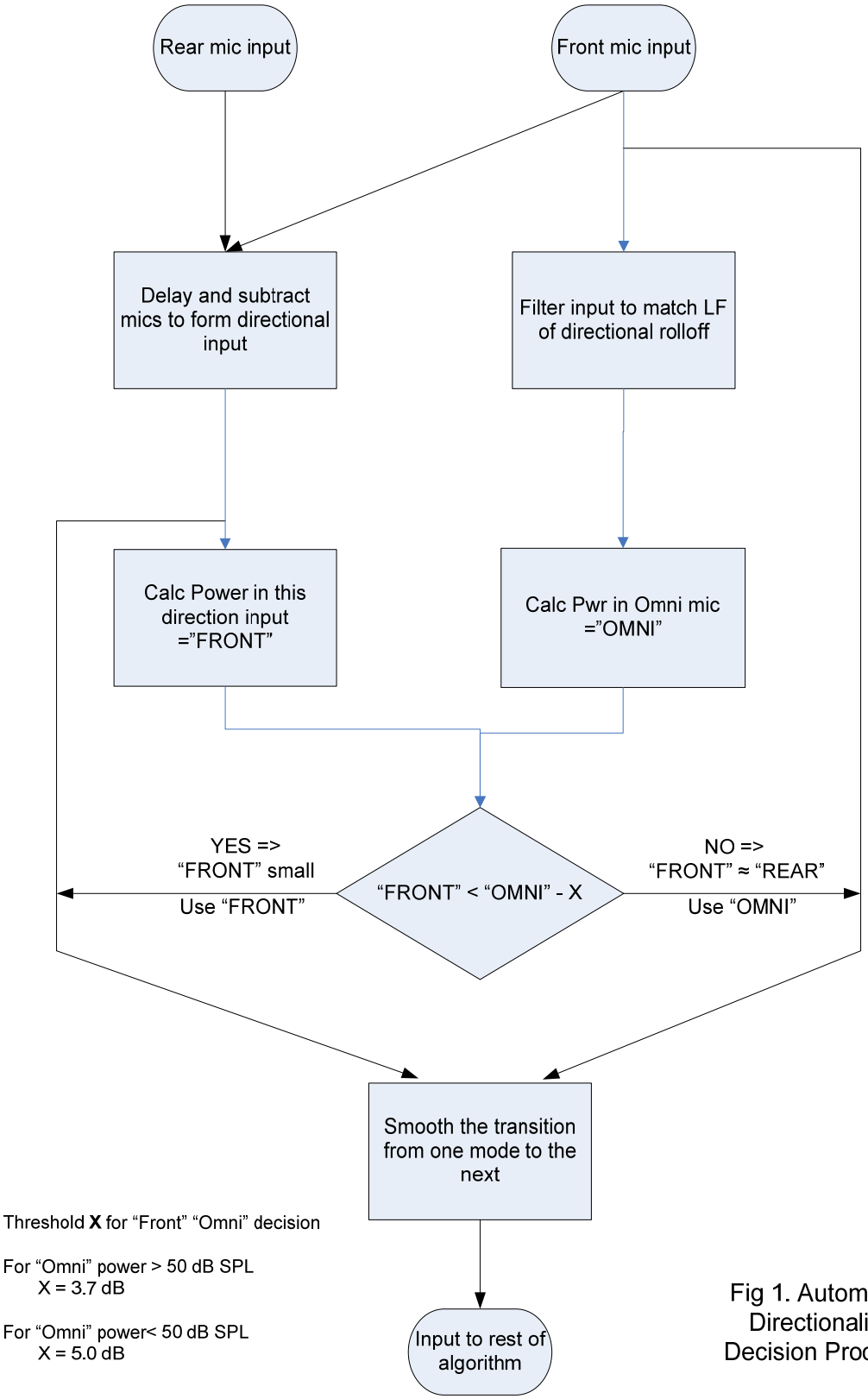
The basic concept is to move to the directional mode under conditions where directionality gives a significant reduction in power. This is determined by comparing the two power levels described above. When the "FRONT" power is much less than the "OMNI" power the directional mode is chosen. When the powers are nearly equal then the omni mode is used. The threshold of the power comparison (referred to as "X" in the flow chart) depends somewhat on the absolute power level. The details of the threshold are given in the chart.

After the decision of which mode to use has been made, there is still one last step. The decision is smoothed so that there is gradual transition between modes. The time constant of the transition is several seconds.

The final result is that when there is a strong noise in the rear and sides of the listener the amplifier switches to the directional mode and the interfering noise is attenuated. Note also that when the switch occurs to the directional mode there is a change in the frequency response in addition to the omni/directional change. In the directional mode there some low frequency attenuation. This can be helpful in highlighting the high frequencies of speech during challenging listening situations.

Examples of Operation of Automatic Directionality

Some examples of the operation of the auto-direct may help to clarify the operation. Consider the case where the only sound source is near-by and directly in front of the hearing aid user. In this case the "FRONT" power is nearly equal to the "OMNI" power. The result is a switch to the omni mode. This is advantageous since it reduces the internal microphone noise. Next, consider when a strong noise source that suddenly appears to the rear of the aid user. Then the "FRONT" power is much less than the "OMNI" power. The algorithm switches to directional mode for this case. The switch occurs over several seconds. The user will hear the noise source gradually become attenuated. This scenario can be simulated in most normal rooms with loud speakers two to three feet from the user. It is a way to test and demonstrate the auto-direct feature.



Threshold **X** for "Front" "Omni" decision

For "Omni" power > 50 dB SPL
X = 3.7 dB

For "Omni" power< 50 dB SPL
X = 5.0 dB

Fig 1. Automatic Directionality Decision Process

Figure 2: Input modes selection box in the 'Slider' software

Table 1: Input Modes in the inTune amplifier

Input selection	Description
AI0 (TC pad)	Signals coming into the TC pad will be routed into the amplifier. Inputs on all other pads are turned off. This input must be external DC decoupled using a capacitor.
AI1 (MIC1 pad)	Signals coming into the MIC1 pad will be routed into the amplifier. Inputs on all other pads are turned off. This input is internally DC decoupled.
AI2 (DAI pad)	Signals coming into the DAI pad will be routed into the amplifier. Inputs on all other pads are turned off. This input must be external DC decoupled using a capacitor.
AI3 (MIC2 pad)	Signals coming into the MIC2 pad will be routed into the amplifier. Inputs on all other pads are turned off. This input is internally DC decoupled.
Fixed Directional - Cardioid pattern	Signals coming into the MIC2 pad are digitized, delayed, and then summed to a digitized MIC1 signal. The delay is adjusted to give a cardioid polar pattern. Microphone calibration is required at manufacturing time to ensure accurate polar responses.
Fixed Directional – Super-cardioid pattern	Signals coming into the MIC2 pad are digitized, delayed, and then summed to a digitized MIC1 signal. The delay is adjusted to give a super-cardioid polar pattern. Microphone calibration is required at manufacturing time to ensure accurate polar responses.
Fixed Directional – Hyper-cardioid pattern	Signals coming into the MIC2 pad are digitized, delayed, and then summed to a digitized MIC1 signal. The delay is adjusted to give a hyper-cardioid polar pattern. Microphone calibration is required at manufacturing time to ensure accurate polar responses.
Adaptive Directional – Cardioid pattern	Signals from the MIC1 and MIC2 inputs are digitized, then analysed to determine whether directional processing or omni processing will give a reduction in noise. The amplifier adapts between omni and cardioid response automatically.
Adaptive Directional – Super-cardioid pattern	Signals from the MIC1 and MIC2 inputs are digitized, then analysed to determine whether directional processing or omni processing will give a reduction in noise. The amplifier adapts between omni and super-cardioid response automatically.
Adaptive Directional – Hyper-cardioid pattern	Signals from the MIC1 and MIC2 inputs are digitized, then analysed to determine whether directional processing or omni processing will give a reduction in noise. The amplifier adapts between omni and hyper-cardioid response automatically.
Fixed Directional – filtered Cardioid pattern	Signals coming into the MIC2 pad are digitized, delayed, and then summed to a digitized MIC1 signal. The delay is adjusted to give a cardioid polar pattern. A low-pass filter boosts the low frequency response to equalized for the natural drop in the LF response due to directional processing. Microphone calibration is required at manufacturing time to ensure accurate polar responses.
Fixed Directional – filtered SuperCardioid pattern	Signals coming into the MIC2 pad are digitized, delayed, and then summed to a digitized MIC1 signal. The delay is adjusted to give a super-cardioid polar pattern. A low-pass filter boosts the low frequency response to equalized for the natural drop in the LF response due to directional processing. Microphone calibration is required at manufacturing time to ensure accurate polar responses.
Fixed Directional – filtered HyperCardioid pattern	Signals coming into the MIC2 pad are digitized, delayed, and then summed to a digitized MIC1 signal. The delay is adjusted to give a hyper-cardioid polar pattern. A low-pass filter boosts the low frequency response to equalized for the natural drop in the LF response due to directional processing. Microphone calibration is required at manufacturing time to ensure accurate polar responses.
MT1	Signals from the TC pad and MIC2 pad inputs are digitized, then added together.
MT2	Signals from the MIC1 pad and DAI pad inputs are digitized, then added together.
Adaptive on/off for Omni/Dir Mic module (uses MIC1 and MIC2)	Signals from the MIC1 and MIC2 inputs are digitized, then analysed to determine whether directional processing or omni processing will give a reduction in noise. The amplifier switches one or the other input on at any given time depending on the analysis results.