# Adaptive Limb Module Technical Description

## Product Description

The Adaptive Limb Module is a prosthetic device designed to provide stance and swing control for Transfemoral amputees. The module contains electronic circuitry to control hydraulic and pneumatic valves such that the stance and swing characteristics can be modified to optimise an amputee's gait. The control circuitry within the Adaptive Limb automatically selects the levels of stance phase support and swing phase assistance according to the type of terrain and walking speed.

The limb control parameters are set up for each amputee during the limb fitting using the Communication Device. High stability support can be programmed for individuals with poor musculature whilst a lower level of support can be programmed for users with greater control of their own residual musculature.

The prosthesis provides stance control ranging from minimal resistance to a yielding lock. It uses sensors to detect different modes; level walking, ramp descent, stair descent, sitting, standing and instances where stumble occurs. The stance resistance is set to a pre-programmed level for the different modes and these levels match the amputee's ability to control the limb.

## Technical Description

The control cylinder, which determines how the Adaptive Limb module swings about the knee joint, comprises of two chambers, one hydraulic and one pneumatic. Each chamber has a motorised valve enabling different hydraulic and pneumatic resistances to be set under electronic control. The module contains two sensors, one to monitor the angle of limb flexion and the other to monitor the vertical load applied to the limb.

The inputs from the two sensors are continually processed by a microcontroller situated within the limb module to determine the mode of locomotion. The positions of the pneumatic and hydraulic control valves are set according to the pre-programmed parameters of the selected mode.

Communication between the limb and the Communication Device is via a bi-directional 914MHz low power radio link. Once the limb has been programmed at a limb fitting centre the power to the transceiver on the limb is disabled. The 914MHz radio link is implemented in both the Adaptive Limb and Communication Device using a proprietary transceiver module. The module is supplied by Radiometrix, part number BiM3-914-64.

Both the Adaptive Limb and Communication Device are designed to be powered from nominal 9 volt battery supplies.

## Modes of Operation

a) Communication Device

   The Communication Device is only used during the fitting stage of the artificial limb for programming and monitoring of function. During this fitting stage the Communication Device sends and receives rf data messages initiated by the operator.

b) Adaptive Limb

   There are six activity states which each have a programmable hydraulic resistance setting. The activity states are standing, sitting, walking on a level surface, walking down a ramp, walking down stairs and stumble. For the walking on a level surface and ramp modes the pneumatic resistance is increased with walking speed. For stairs descent mode it is set to a maximum, for standing and sitting modes to a minimum and for stumble mode the currently selected pneumatic resistance is retained.

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i) Set Up (Program) Mode
During the fitting stage of the limb the hydraulic and pneumatic resistance levels are programmed and the activity state selection thresholds determined. This programming sequence would normally be carried out by a practitioner using the Communication Device to remotely interact with the limb to make the necessary adjustments to the activity state detection and control parameters. Once the limb has been programmed to meet the amputee's particular gait characteristics all data to activate the activity states is retained in non-volatile memory on the limb controller circuit board. The rf transceiver on the limb is powered on by a specific activation sequence to enable communication between the limb and Communication Device. Once the fitting is complete the rf transceiver is automatically disabled.

ii) Normal Operation
The limb provides stance and swing control for the amputee as he or she goes about their daily function. The force and swing sensors are continually monitored and the measured data is processed to determine the current activity state. The motorised hydraulic and pneumatic valves are then driven to the corresponding positions determined in set up mode to activate the required hydraulic and pneumatic resistance settings.

## RF Communication Protocol

A bi-directional RF 914MHz communication link is set up between the Communication Device and the Adaptive Limb Controller Board. Data is sent in 8 byte packets at data rate of 9600 baud.

The structure of the data packet is as follows:

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| channel | -channel | command | -command | data1 | -data1 | data2 | -data2 |

Each packet contains 4 bytes of information, channel (which is also used as the start byte), command and 2 data bytes and the inverse of each of these bytes making a total of 8 bytes. The inverse bytes are used to check the integrity of the packet. If any of the 2 byte pairs do not verify then the whole data packet is rejected. Before each data packet is sent a 4 byte preamble sequence is transmitted to allow the receiving device to synchronise to the transmitting device.

During communication the Communication Device is the master and the Limb Controller is the slave. The default state is Communication Device in transmit mode and Limb Controller in receive mode. The communication protocol timing is as follows:

**COMMUNICATION DEVICE**

| TRANSMIT PACKET | SELECT RX MODE | READY TO RECEIVE DATA (TIMEOUT AFTER 64ms) | SELECT TX MODE | WAIT | READY TO TRANSMIT |
|---|---|---|---|---|---|
| 12ms | 4ms | upto 64ms | 4ms | 16ms | |

**LIMB CONTROLLER**

| RECEIVE PACKET | SELECT TX MODE | WAIT | TRANSMIT REQUESTED DATA | SELECT RX MODE | READY TO RECEIVE |
|---|---|---|---|---|---|
| 12ms | 4ms | 4ms | upto 60ms | 4ms | |

The Limb Controller will only transmit a data packet in response to a request from the Communication Device.