AFDX® Workshop

Avionics Databus Solutions

- Network Overview and Topology
- Virtual Link Concept
- Redundancy / Integrity Checking
- Protocol Layers
- Payload Organisation

AFDX a registered trademark of Airbus Deutschland GmbH
AFDX Workshop

AFDX – Avionics Full Duplex Switched Ethernet

- 100Mbit/sec / 10Mbit/sec, first 1GBit/sec implementations available!
- Built around commercial Ethernet (MAC, IP, UDP, SNMP) with provisions for deterministic behaviour
- Media is Copper or Fibre Optic
- 3 Types of Network elements
  - End Systems (E/S)
  - Switches
  - Links
- Why AFDX?
  High Speed Commercial Ethernet with provisions for guaranteed Deterministic Timing and Redundancy required for Avionics applications
AFDX – Avionics Full Duplex Switched Ethernet

- related Standards (most important), www.arinc.com

**AIRCRAFT DATA NETWORK**
**PART 7**
**AVIONICS FULL DUPLEX SWITCHED**
**ETHERNET (AFDX) NETWORK**
**ARINC SPECIFICATION 664P7**
**PUBLISHED: June 27, 2005**

**AIRCRAFT DATA NETWORKS**
**PART 2**
**ETHERNET PHYSICAL AND DATA-LINK LAYER**
**SPECIFICATION**
**ARINC SPECIFICATION 664**
**PUBLISHED: JUNE 10, 2003**
AFDX Workshop

AFDX – Avionics Full Duplex Switched Ethernet

- related Specifications (most important), AIRBUS proprietary

**AFDX END SYSTEM DETAILED FUNCTIONAL SPECIFICATION**
L42D1515045801

**AFDX SWITCH DETAILED FUNCTIONAL SPECIFICATION**
L42D1515051901

**AFDX MESSAGE FORMATS DETAILED FUNCTIONAL SPECIFICATION**
L42D1 515.1722/01

**RULES FOR THE CONSTRUCTION OF AFDX MESSAGES**
L42D1 515.0004/2002
AFDX Workshop

Topology

- AFDX is a network architecture
- There are two types of devices:
  - **Switch**: A device which performs traffic policing and filtering, and forwards packets towards their destination End-Systems.
  - **End-System**: A device whose applications access the network components to send or receive data from the network.
- All connections are full duplex, 100Mbits/sec (no dedicated backbone bus for Inter-switch communications)
- Redundancy is achieved by duplication of the connections (wires) & Switches
AFDX Workshop

Communication Techniques

- AFDX Communication protocols have been derived from commercial standards
  - IEEE802.3 Ethernet MAC addressing
  - Internet Protocol IP
  - User Datagram Protocol UDP
  - SNMP
  - ICMP

- Provisions have been added to ensure Deterministic Behaviour
- End-Systems perform traffic shaping which is enforced by Switches
- Switches perform traffic policing and static routing of frames
Virtual Link (VL) Definition

- End-Systems exchange Frames through Virtual Links (VLs)
- A Virtual Link defines a unidirectional (logical) connection from one source End-System to one or more destination End-Systems → “Uni- or Multicast” communication
Virtual Link Definition

- An AFDX network can define up to 64k ($2^{16}$) VLs identified by a 16-Bit identifier in the MAC Destination Field of Ethernet Frame.

- An AFDX End-Systems can support multiple VLs.

- End-Systems perform Traffic shaping and Integrity Checking on each VL.

- A Switch performs Traffic policing on each VL.

- Traffic shaping and policing combined, offer the baseline for deterministic behaviour of the network.
## Virtual Link Parameters Overview

<table>
<thead>
<tr>
<th>Parameter</th>
<th>E/S</th>
<th>Switch</th>
</tr>
</thead>
<tbody>
<tr>
<td>BAG (Bandwidth allocation GAP)</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Frame Size</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>max. allowed Jitter</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>No. of Sub-VLs</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Account Type</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Priority</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Network Selector</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Skew Max.</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>
AFDX Workshop

Virtual Link Parameters

- Bandwidth Allocation Gap (BAG):
  - The End-System controls the transmission flow for each VL in accordance with the BAG (traffic shaping)
  - The Switch verifies the BAG (traffic policing)
Virtual Link Parameters

- Bandwidth Allocation Gap (continued):

  - Frames do not need to be transmitted exactly in multiples of the configured BAG
    Example: a “Sampling” service with 20ms rate on VL with 4ms BAG
    → every 20ms a valid frame appears on the network,
    → the Sampling Service uses < 100% of the VL bandwidth

  - Frames on a VL can be transmitted slower than the BAG without impact on the Switching (see above)

  - if no data are available to send on a VL, no frames appear

  - Frames on a VL can be transmitted faster than the BAG with impact on the Switching (traffic policing)
    (see at “Jitter” Parameter for details).
Virtual Link Parameters

- Bandwidth Allocation Gap (continued):
  - BAG values are in milliseconds: 1, 2, 4, 8, 16, 32, 64, 128
  - Per VL a maximum of 1000/ BAG Frames per second can be transmitted.
Virtual Link Parameters

- **Frame Size $S_{\text{max}}$:**
  - Each VL max. Frame Size $S_{\text{max}}$ can be individually configured
  - $S_{\text{max}} = \{64, \ldots, 1518\}$
  - Together with the BAG, the absolute (worst case) bandwidth consumption on an AFDX link can be calculated for a given VL
  - Frames on a VL can have different Frame sizes $S$: $64 \leq S \leq S_{\text{max}}$
Virtual Link Parameters

- **Frame Size (continued):**

- The End System has to maintain the Frame size for all transmitted frames with respect to the configured max. Frame Size for each VL e.g. IP Fragmentation

- The Switch checks for the max. Frame Size and maintain its “Accounts” for handling the forwarding (e.g. Byte-based vs. Frame-based filtering )

![Diagram showing Frame arrival]
Virtual Link Parameters

- **Jitter (in General):**
  - The difference between the minimum and maximum time from when a source node sends a message to when the sink node receives the message.
  - Jitter is generally a function of the network design and multiplexing multiple VLs on one port as well as dependent on the Switch.
  - For a VL, frames can appear on the link in a given time interval (Window) which is sized by the BAG and the maximum allowed jitter.
Virtual Link Parameters

- maximum allowed Jitter:
  - The maximum allowed Jitter is configuration parameter of the Switch for maintaining the “Account” for each VL (traffic policing).
  - Allowing a Jitter for a VL make the Switch more “tolerant” for frames appearing faster than the BAG by increasing the “Account”:

\[
Account = s_i^{max} \cdot \left(1 + \frac{J_{switch}}{BAG_i}\right)
\]

(e.g. max. allowed Jitter 0.5ms, BAG 1ms → Smax * 1.5)
Virtual Link Parameters

- maximum allowed Jitter (continued):
  - The End System has to maintain the traffic flow (→ traffic shaping) in order to achieve the Jitter <= max. allowed Jitter
Virtual Link Parameters

- **Sub-VLs (E/S relevant only):**
  - Each VL may consist of up to 4 sub-VLs
  - There is a Round-Robin Scheduling of sub VL’s
  - sub-VL assignment is **not** encoded in the frame → cannot be directly resolved (vs, VL)

![Diagram showing IP, Sub-VL FIFOs, MUX, VL FIFO, and BAG = 1ms)]
Virtual Link Parameters

- Account Type and Priority (Switch relevant only):
  - the Account Type defines if the Switch maintains individual Accounts for every VL or shared Accounts between multiple VLs
  - the Priority is a VL related configuration parameter of the Switch to group VLs in Low or High priority groups, with different internal handling of the forwarding
AFDX Workshop

Virtual Link Parameters

- Network Selector and Skew Max (E/S relevant only):
  - These parameters are basically important in conjunction with the Redundancy Management (see following pages)
AFDX Integrity Checking

- Integrity checking is done per VL and per Network

- Checking is based on Sequence Number (SN) and the so called “Maximum Consecutive Frames Lost”
  - The Sequence numbering is performed for each VL individually

- All Invalid Frames are discarded (e.g. with physical errors)
AFDX Workshop

AFDX Redundancy Management

- The Ports, Links and Switches are duplicated for redundancy
  - Switch does not need to know about redundancy (duplicated)
  - E/S needs to know about redundancy (not duplicated!)

* The Networks are sometimes also called „Red“ and „Blue“
AFDX Redundancy Management

- Frames are concurrently transmitted over both networks (if VL is configured accordingly \(\rightarrow\) Network Selector “A and B”, “A only” and “B only” may be also configured for VLs)

- on the Receiving End-System, “First Valid Frame wins” which requires provisions for this algorithm e.g. the SN
AFDX Workshop

AFDX Redundancy Management

missing frame
AFDX Workshop

Redundancy Management & Integrity Checking

End System

A Network

Mac Layer

Integrity Checking: Detect and eliminate invalid frames

Redundancy Management: Eliminate redundant frames

IP, UDP, TCP Layers

B Network

Mac Layer

Integrity Checking: Detect and eliminate invalid frames

Application

Network Management
AFDX Protocol Layers

- Avionics applications residing at End-Systems exchange messages via the services of the **User Datagram Protocol Layer** (*UDP*, Layer 4) with underlying **Internet Protocol** (*IP*, Layer 3)

- The UDP Protocol is also the base for upper layer protocols for maintenance purposes (**SNMP** Simple Network Management Protocol) and File Transfer Services (**TFTP** Trivial File Transfer Protocol)

- End Systems also have to support **ICMP** Internet Control Message Protocol based on *IP* protocol, but still residing in Layer 3. (known as “Ping command”, “Echo Request/Reply” on ICMP)

- AFDX Switching is based on the **MAC Destination Address** (Layer 2)
- AFDX provisions for deterministic are implemented on Layer 2 only
AFDX Workshop

AFDX – Protocol Layers

AFDX Training
AFDX Workshop

AFDX Frame Structure

<table>
<thead>
<tr>
<th>Preamble</th>
<th>Start Delimiter</th>
<th>MAC Header</th>
<th>IP Header</th>
<th>UDP Header</th>
<th>AFDX Payload</th>
<th>AFDX Sequence Number</th>
<th>FCS</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>1</td>
<td>12</td>
<td>22</td>
<td>8</td>
<td>17...1471</td>
<td>1</td>
<td>4</td>
</tr>
</tbody>
</table>

Frame Size: 64...1518 Bytes

Preamble + Start Delimiter + InterFrame Gap: 20 Bytes

Duration of Minimum Frame: 6.72 usec (84 Bytes a 80ns)

Duration of Maximum Frame: 123.04 usec (1538 Bytes a 80ns)
AFDX Frame Structure

- Frame Size Terminology (Source: ARINC664)
AFDX Workshop

AFDX – MAC Layer 2

- MAC header comprises a Source and Destination Address, and a Type Field
- Each address is 48 bits wide
- The Destination Address identifies the Virtual Link
- The Source Address is (must be) a Unicast Address
- The Destination Address is (must be) a Multicast Address

<table>
<thead>
<tr>
<th>Preamble</th>
<th>Start Delimiter</th>
<th>MAC Dest Addr</th>
<th>MAC Source Addr</th>
<th>Type</th>
<th>Ethernet Payload</th>
<th>FCS</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>1</td>
<td>6</td>
<td>6</td>
<td>2</td>
<td>46…1500</td>
<td>4</td>
</tr>
</tbody>
</table>
AFDX Workshop

AFDX – MAC Layer Layer 2

- MAC Source Address encodes the unique “Source” of the frame

<table>
<thead>
<tr>
<th>Preamble</th>
<th>Start Delimiter</th>
<th>MAC Dest Addr</th>
<th>MAC Source Addr</th>
<th>Type</th>
<th>Ethernet Payload</th>
<th>FCS</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>1</td>
<td>2</td>
<td>46...1500</td>
<td>4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Constant Field
0000 0010 0000
0000 0000 0000

24 bits

Network ID

<table>
<thead>
<tr>
<th>Domain ID</th>
<th>Side ID</th>
<th>Location ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>0000</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Equipment ID

<table>
<thead>
<tr>
<th>Interface ID</th>
<th>000000</th>
</tr>
</thead>
</table>

3 5 3 5
AFDX – MAC Layer Layer 2

- MAC Destination Address identifies the Virtual Link

<table>
<thead>
<tr>
<th>Preamble</th>
<th>Start Delimiter</th>
<th>MAC Dest Addr</th>
<th>MAC Source Addr</th>
<th>Type</th>
<th>Ethernet Payload</th>
<th>FCS</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td></td>
<td>2</td>
<td>46...1500</td>
<td>4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Constant Field

| 0000 0011 0000 0000 0000 0000 0000 0000 |

Virtual Link Identifier

32 bits

16 bits
AFDX Workshop

AFDX – MAC Layer Layer 2

- The IP Type Field defines IPv4 support only (today)

<table>
<thead>
<tr>
<th>Preamble</th>
<th>Start Delimiter</th>
<th>MAC Dest Addr</th>
<th>MAC Source Addr</th>
<th>Type</th>
<th>Ethernet Payload</th>
<th>FCS</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>1</td>
<td>6</td>
<td>6</td>
<td>2</td>
<td>46…1500</td>
<td>4</td>
</tr>
</tbody>
</table>

- IPv4 0x0800

16 bits
AFDX Workshop

AFDX – MAC Layer Layer 2

- MAC Addressing

- The MAC Source address identifies a system wide unique source equipment (End System) → always “Unicast”

- The MAC Destination address is always a “Multicast” address (No Broadcasts allowed !) and a receiving equipment can handle multiple MAC Destination addresses resp. VLs !
AFDX Workshop

AFDX – IP (Internet Protocol) Layer 3

- IPv4 Header

```
+----------------+----------+-------------------+-------------------+----------+----------+----------
| Preamble | Start Delimiter | MAC Header | IP Header | IP Payload | FCS |
+----------+-----------------+-----------+-----------+-----------+-----
| 7        | 1               | 14        |           | 26...1480 | 4   |
```

```
| Version   | IHL | Type of Service | Total length | Fragment identification | Control Flag | Fragment Offset | Time to Live | Protocol | Header checksum | IP Source Address | IP Destination Address |
+-----------+-----+-----------------+--------------+-------------------------+--------------+-----------------+--------------+---------+-----------------+----------------------+------------------------|
| 4         | 4   | 8               | 16           | 16                     | 3            | 13              | 8           | 8       | 16             | 32                   | 32                     |
```
AFDX Workshop

AFDX – IP (Internet Protocol) Layer 3

- IP Unicast Source and Destination Address

<table>
<thead>
<tr>
<th>Preamble</th>
<th>Start Delimiter</th>
<th>MAC Header</th>
<th>IP Header</th>
<th>IP Payload</th>
<th>FCS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version</td>
<td>IHL</td>
<td>Total length</td>
<td>Fragment identification</td>
<td>Control Flag</td>
<td>Fragment Offset</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Constant Field: 0000 1010

- 8 bits

- Network ID: 1000

- Domain ID: 4

- Equipment ID: 000

- Side ID: 3

- Location ID: 5

- Partition ID: 3

- Partition ID: 5
AFDX Workshop

AFDX – IP (Internet Protocol) Layer 3

- IP Multicast Destination Address

<table>
<thead>
<tr>
<th>Preamble</th>
<th>Start Delimiter</th>
<th>MAC Header</th>
<th>IP Header</th>
<th>IP Payload</th>
<th>FCS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version</td>
<td>IHL</td>
<td>Type of Service</td>
<td>Total length</td>
<td>Fragment identification</td>
<td>Control Flag</td>
</tr>
</tbody>
</table>

Constant Field
1110 0000 1100 0000

16 bits

Virtual Link Identifier

16 bits
AFDX Workshop

AFDX – IP (Internet Protocol) Layer 3

**IP Addressing**

- **IP Source** is always a Unicast Address, Class A Private IP (→ single source) Example: 10.x.x.x

- **IP Destination** either Multicast (→ multiple receivers* in a End System e.g. 224.224.x.x) or Unicast (→ single receiver* in End System e.g. 10.x.x.x)

* A “receiver” e.g. means an application. In other words: data addressed to a unicast IP destination address shall be used by only one application, data addressed to a multicast IP destination address can be used by multiple applications in the same End System. The Specifications are also using the term “partition” in sense of an “application”.
AFDX Workshop

AFDX – IP (Internet Protocol) Layer 3

data source always Unicast

data destination Unicast

to MAC Layer

data destination Multicast

from MAC Layer
AFDX Workshop

AFDX – IP (Internet Protocol) Layer 3

- IP Fragmentation
  
  - In the IP Layer message data (up to 8kByte for AFDX) are fragmented for transmission via multiple MAC Frames (if necessary)
  
  - Fragmentation is a standard functionality if the IP Layer (not AFDX specific), however for AFDX the fragments are expected always “in order”
  
  - IP Layer needs to respect the max. Frame size of associated VL!
  
  - on receiving side the IP Reassembly is the counterpart
AFDX Workshop

AFDX – IP (Internet Protocol) Layer 3

- IP Fragmentation (simplified)

Application Data $D$ up to 8kByte

Fragmentation

Frame $D_1$  Frame $D_2$  ...  Frame $D_n$

Data Link Layer 2

IP Layer 3

Application Layer 7

Application Data $D'$ up to 8kByte

Reassembly

© AIM GmbH March 2010
No publishing without permission of AIM GmbH
AFDX – UDP (User Datagram Protocol) Layer 4

**UDP Header**

- **Preamble**
- **Start Delimiter**
- **MAC Header**
- **IP Header**
- **UDP Header**
- **UDP Payload**
- **FCS**

<table>
<thead>
<tr>
<th>Preamble</th>
<th>Start Delimiter</th>
<th>MAC Header</th>
<th>IP Header</th>
<th>UDP Header</th>
<th>UDP Payload</th>
<th>FCS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Source Port**: 16 bits
- **Destination Port**: 16 bits
- **UDP length**: 16 bits
- **UDP Checksum**: 16 bits

- **Start Delimiter**: 1 byte
- **MAC Header**: 14 bytes
- **IP Header**: 20 bytes
- **UDP Header**: 8 bytes
- **UDP Payload**: 18...1472 bytes
- **FCS**: 4 bytes
AFDX Workshop

AFDX – UDP (User Datagram Protocol) Layer 4

UDP port x Source → IP Source → MAC destination = VL
UDP port y Source
UDP port z Source

IP Destination

UDP port m destination
UDP port n destination
UDP port o destination

Message 1 → Message 2 → Message 3

Message 1
Message 2
Message 3
Applications send/receive “messages” through AFDX Comm(unication) Ports which are basically mapped to UDP Ports.

There are two types of AFDX Comm Ports which detailed characteristics are defined by the ARINC653 Standard (AVIONICS APPLICATION SOFTWARE STANDARD INTERFACE):

- **Queuing Ports** - AFDX messages may be sent over several AFDX frames (fragmentation by IP layer dependent on the associated VL Max. frame size), no data is lost or overwritten. The max. amount of data handled per queuing port is 8kByte.

- **Sampling Ports** - AFDX messages are sent in one Frame, data may be lost or overwritten. The max. amount of data handled per sampling is limited by the associated VL max. Frame size.
AFDX UDP Protocol

Diagram:

AFDX Comm Port

UDP Port

UDP
AFDX Workshop

AFDX UDP Protocol

- AFDX Comm Ports are typically associated with a “Quintuplet” consisting of
  - *UDP Source Port Number*
  - *UDP Destination Port Number*
  - *IP Source Address*
  - *IP Destination Address*
  - *Virtual Link Number*

- AFDX Comm Port types can be either Send or Receive ports
- Structuring of the AFDX Payload Data (=UDP Payload) defined in ARINC664 P7 and Airbus proprietary specifications.
- A special type of UDP Ports are called SAP (Service Access Point)
AFDX Payload Summary

- AFDX Payload is carried in one (Sampling and Queuing Ports) or multiple Frames (Queuing Ports) via UDP Protocol

- IP Fragmentation / Reassembly is used for transmission of up to 8 kByte payload data

- UDP Header only in first frame of fragmented a “message”!
  The Fragmentation Information is handled via IP Header
AFDX Payload for no-protocol based data is organized in so called Functional Data Sets (FDS)
A Functional Data Set (FDS) is organized into Functional Status Set (FSS) and Data Sets (DS)
A Data Sets (DS) typically contains a Parameter (Datum) e.g. Float, Integer, Enumerated, Boolean, ……
# AFDX Glossary

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>AFDX</td>
<td>Avionics Full Duplex Switched Ethernet</td>
</tr>
<tr>
<td>E/S</td>
<td>End System</td>
</tr>
<tr>
<td>VL</td>
<td>Virtual Link</td>
</tr>
<tr>
<td>MAC</td>
<td>Media Access Control</td>
</tr>
<tr>
<td>IP</td>
<td>Internet Protocol</td>
</tr>
<tr>
<td>UDP</td>
<td>User Datagram Protocol</td>
</tr>
<tr>
<td>SAP</td>
<td>Service Access Point</td>
</tr>
<tr>
<td>TFTP</td>
<td>Trivial File Transfer Protocol</td>
</tr>
<tr>
<td>API</td>
<td>Application Programming Interface</td>
</tr>
<tr>
<td>OSI</td>
<td>Open Systems Interconnection</td>
</tr>
<tr>
<td>BAG</td>
<td>Bandwidth Allocation Gap</td>
</tr>
<tr>
<td>SNMP</td>
<td>Simple Network Management Protocol</td>
</tr>
<tr>
<td>MIB</td>
<td>Management Information Base</td>
</tr>
<tr>
<td>TCP</td>
<td>Transmission Control Protocol</td>
</tr>
<tr>
<td>ICMP</td>
<td>Internet Control Message Protocol</td>
</tr>
<tr>
<td>ICD</td>
<td>Interface Control Document</td>
</tr>
<tr>
<td>NCD</td>
<td>Network Control Document</td>
</tr>
<tr>
<td>ISDB</td>
<td>Integrated Systems Data Base</td>
</tr>
<tr>
<td>ARINC</td>
<td>Aeronautical Radio Incorporated</td>
</tr>
<tr>
<td>RM</td>
<td>Redundancy Management</td>
</tr>
<tr>
<td>IC</td>
<td>Integrity Checking</td>
</tr>
</tbody>
</table>
Our Mission is your Success!

- **AIM GmbH**
  Sasbacher Str. 2
  79111 Freiburg
  Germany
  Tel:  +49 761 45 22 90
  Fax:  +49 761 45 22 93 3
  email: sales@aim-online.com

- **AIM München Sales Office**
  Terofalstrasse 23a
  80689 München
  Germany
  Tel:  +49 89 70 92 92 92
  Fax:  +49 89 70 92 92 94
  email: salesgermany@aim-online.com

- **AIM UK**
  Cressex Enterprise Centre
  Lincoln Road, High Wycombe, Bucks
  United Kingdom
  Tel:  +44 1494 446844
  Fax. +44 1494 449324
  email: salesuk@aim-online.com

- **AIM-USA**
  Seven Neshaminy Interplex - Suite 211
  Trevose, PA 19053
  USA
  Tel:  267-982-2600/ 1-877-520-1553
  Fax:  215-645-1580
  email: salesusa@aim-online.com