

# AEROSPACE INFORMATION REPORT

**SAE** AIR5601

Issued 2005-06

## A Guideline for Application of RF Photonics to Aerospace Platforms

### FOREWORD

This document was developed by the SAE AS-3A-2 RF/Analog Technology Task Group under AS-3 Fiber Optics and Applied Photonics and AS-3A Applications. The formation of this task group was approved at the fall meeting of the SAE AS-3 committee in October 2002. While RF photonics technology can potentially provide enormous benefits to future aerospace platforms, the technology is significantly different from conventional RF technology and requires engineers to think in somewhat new terms and adapt to the peculiarities of the medium. Establishment of guidelines for the application of RF photonics technology will assist avionics systems suppliers and customers in the design, development, and testing of future systems which incorporate photonics networks that include analog RF signal transmission. This document is dedicated to that goal. There are many contributors to be recognized for their efforts in developing this document and the AS-3 Fiber Optics and Applied Photonics Committee is grateful for everyone's contributions. Unfortunately we cannot list the names of individuals in this document.

The intended audience for this work is new engineering graduates, experienced engineers who are new to fiber optics and managers who are new to fiber optics or have been away from day-to-day exposure to fiber optics for a while. Realizing that the SAE is an international organization and that information published by the SAE is available worldwide, the information contained herein is limited to that which is also available independently from the various companies which provided it. This document only serves to gather and collate the information from the many various sources to facilitate the understanding and utilization of RF/Analog signals transmitted over fiber-optic networks.

SAE Technical Standards Board Rules provide that: "This report is published by SAE to advance the state of technical and engineering sciences. The use of this report is entirely voluntary, and its applicability and suitability for any particular use, including any patent infringement arising therefrom, is the sole responsibility of the user."

SAE reviews each technical report at least every five years at which time it may be reaffirmed, revised, or cancelled. SAE invites your written comments and suggestions.

Copyright © 2005 SAE International

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise, without the prior written permission of SAE.

**TO PLACE A DOCUMENT ORDER:**

**Tel: 877-606-7323 (inside USA and Canada)**

**Tel: 724-776-4970 (outside USA)**

**Fax: 724-776-0790**

**Email: [custsvc@sae.org](mailto:custsvc@sae.org)**

**<http://www.sae.org>**

**SAE WEB ADDRESS:**



*Leading Our World In Motion*

## SAE AIR5601

This task group was formed with an open invitation to professionals in government and at major platform developers and suppliers of photonics systems and components. Beginning with a few contacts from SAE and existing programs, the call went out: who do you know with RF photonics expertise? From these new contacts: who do you know? So I call this task group the "who do you know, who do you know group". These are professionals known by their peers as experts in the field of RF photonics technology. They have worked on a volunteer basis with the support of their company or organization to develop a document that defines the current art of RF photonics. I am indebted to them and their organizations for their dedication to this effort.

SAE AIR5601

TABLE OF CONTENTS

1.	SCOPE .....	9
2.	REFERENCES.....	9
2.1	List of Acronyms.....	9
3.	RF PHOTONICS AEROSPACE APPLICATIONS AND ADVANTAGES .....	15
3.1	Advantages of Photonics in RF Systems .....	16
3.1.1	Electromagnetic Interference (EMI) Resistance.....	16
3.1.2	Superior Phase Stability.....	17
3.1.3	Extremely Low Optical Transmission Loss Leading to Platform Independence .....	17
3.1.4	Small Size/Light Weight Cabling .....	17
3.1.5	Extremely Wide Bandwidth .....	17
3.1.6	Growth Capability and Scalability.....	18
3.1.7	Survivability and Vulnerability .....	18
3.2	Signal Distribution and Delay Applications.....	18
3.2.1	Antenna Remoting and Signal Distribution .....	18
3.2.2	RF Delay Lines.....	20
3.2.3	Use of RF Delay Lines for Radar Testing or False Target Generation .....	22
3.2.4	Use of Wavelength Division Multiplexing to Replace RF Switching.....	22
3.2.5	True Time Delay Beamforming .....	25
3.3	Signal Processing and Generation Applications .....	26
3.3.1	RF Signal Generation Using Photonic Processes.....	26
3.3.2	RF-Photonic Methods for Frequency Conversion .....	27
3.3.3	RF-Photonic Transversal Filters.....	29
3.3.4	RF-Photonic Sampling of Analog Waveforms.....	30
3.3.5	Use of RF Photonics in Digital Systems.....	31
3.4	Summary.....	33
4.	RF PHOTONICS SYSTEMS CONSIDERATIONS.....	34
4.1	Frequency Bands of RF Systems .....	34
4.2	RF Systems Architecture with Insertion of Photonics Technologies .....	35
4.2.1	Suitability of Multi-Mode Optical Fiber for RF-Photonic Systems.....	35
4.2.1.1	Characteristics of Multi-Mode Optical Fibers .....	35
4.2.1.2	Performance Limitations of RF-Photonic Links with Multi-Mode Optical Fibers.....	36
4.2.1.3	Use of Multi-mode Fiber with Multi-Mode Photonic Devices .....	40
4.2.2	Selection of Optical Wavelength for RF-Photonic System .....	41
4.2.3	RF-Photonic Signal Distribution and Switching Architectures.....	43
4.2.4	Considerations for Multiplexing of Analog and Digital Signals .....	46
4.2.4.1	Optical Non-Linearities in Fiber.....	47
4.3	Modulation Techniques for RF Photonic Applications.....	48
4.3.1	Intensity Modulation .....	49
4.3.2	Frequency Modulation.....	49
4.3.3	Phase Modulation .....	50
4.3.4	Subcarrier Multiplexing (SCM) .....	50