Final Report

Standards preparation for SOTM terminals

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Participating Partners / Authors:

Fraunhofer Institute for Integrated Circuits IIS:
Mostafa Alazab, Florian Raschke, Dr.-Ing. Markus Landmann

Global VSAT Forum GVF:
Colin Robinson, Martin Jarrold, David Hartshorn

Submitted by the Project Coordinator:

Fraunhofer Institute for Integrated Circuits IIS:
Project Group Wireless Distribution Systems / Digital Broadcasting
Markus Landmann
Phone: +49 (0) 3677 69-4297, Fax: +49 (0) 3677 69-4282
markus.landmann@iis.fraunhofer.de / alazabma@iis.fraunhofer.de
Helmholtzplatz 2
98693 Ilmenau, Germany

EUROPEAN SPACE AGENCY CONTRACT REPORT.

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1. Introduction

1.1 Scope of the document

This document describes the work performed in the context of the ESA Contract number 4000112640 (under the ESA ARTES 1 Programme).

1.2 Structure of the document

This document is structured in Chapters as follows: Chapter 1 provides an introduction. In Chapter 2 and Chapter 3, the objectives and the study logic of the project are introduced. Chapter 4 presents the results of reviewing the current SOTM value chain. In Chapter 5, product sheets of different SOTM products have been reviewed while extracting the main parameters used to define the product performance. Moreover, the current SOTM buying process is analysed. Chapter 6 shows the results of implementing a consultation plan where different market contributors have been interviewed and their feedback was evaluated as a step in the process of improving the performance of the whole SOTM market chain. The results are then used to describe a standard for a framework used to evaluate the performance of SOTM products as explained in Chapter 7. Chapter 8 provides final comments and conclusions.

1.3 Project deliverables and corresponding work packages

The following table lists the deliverables of the project as described in the Statement of Work (SOW). The related sections in this document are provided for reference.

No.	Deliverable as per the project proposal	Submitted document	Related section in final report
1	TN1.1 Value chain consolidation	TN1_ARTES1_GVF_FHG.pdf	6
2	TN2.1 Current buying process	TN2_ARTES1_GVF_FHG.pdf	18
3	TN2.2 Possible improvements to the current buying process	TN2_ARTES1_GVF_FHG.pdf	45
4	TN3.1 Consultation plan	TN3_ARTES1_GVF_FHG.pdf	62
5	TN3.2 Transaction needs	TN3_ARTES1_GVF_FHG.pdf	64
6	TN4.1Standards recommendation	TN4_ARTES1_GVF_FHG.pdf	81
7	TN4.2 Standards implementation plan	TN4_ARTES1_GVF_FHG.pdf	83
8	Final report	FinalReport_ARTES1.pdf	-
9	Executive summary report	ExecutiveSummary_ARTES1.pdf	-
10	Final presentation	Date to be confirmed!	-
11	Project web page		-

2. Objectives

The objective of this study is to determine a common scope for the specification and verification of Satcom On-The-Move SOTM terminals. The activity led to recommendations for future standards that will allow players in the market, such as service providers, satellite operators, and end users, to clearly understand the capabilities of SOTM terminals without having to undergo multiple expensive and lengthy validation campaigns themselves before investing in and deploying a product.

3. Study Logic

This activity consists of 4 main tasks as shown in Figure 1. The first two tasks deal with understanding and analysing the current SOTM market conditions. The way the performance of SOTM products is specified and evaluated was judged by analysing the specification sheets of different off-the-shelf products. The SOTM value chain and the current buying process from the manufacturer to the end-users were analysed in order to identify the main problems and inefficiencies. In task 3, the actors of the value chain were approached. A consultation plan to understand the needs and visions of the key contributors was implemented. Task 4 formulated recommendations for how the performance of SOTM products can be evaluated in an efficient way by reducing the cost of product qualification.

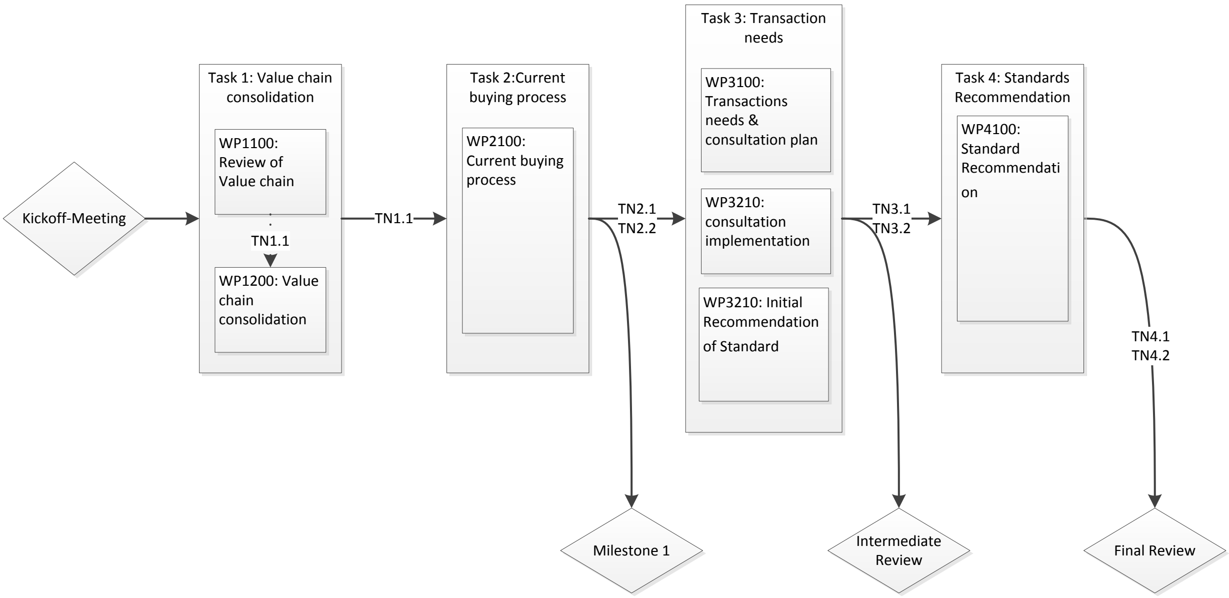


Figure 1: Block diagram summarizing the study logic of this project

4. Value Chain Consolidation

This task was divided into two main subtasks: Review of the SOTM value chain as per Work Package WP1100 and a detailed analysis of key companies and products as per WP1200. The objectives are to refine the existing value chain of each environment (land mobile, maritime and aeronautical), identify the role of each company and show how the performance of their products is specified.

4.1 Value Chain Review

A list identifying manufacturers, satellite service providers, integrators and value added re-sellers that have involvement with the mobile satellite communications market was deliberately prepared to act as the basic pillar of this study. The list segregates the SOTM market into key categories. Examples include maritime, land mobile, aeronautical and high speed rail etc. New entrants to the SOTM market have been identified and their potential to gain foothold in the future market place was addressed. The list was submitted as a deliverable of the project.

Precedence has been given to EU and Canadian based organisations. International organisations with significant operations in Europe were also evaluated. The scope of this ESA study guidelines also permits input from non-European to be considered where it adds value to the overall study objectives.

The value chain has been broken down in the three major categories listed in sections 4.1.1 through 4.1.3. While the environments and specifications relevant to each of these categories may differ, all products are required to be qualified by the same general standards (antenna pattern performance, cross pol discrimination, uplink power spectral density, frequency stability, pointing accuracy etc.) These are established by the ITU at the global level and by satellite operators and governmental regulatory agencies at the local level covering the jurisdiction for the various regions in which the terminals are deployed. SOTM terminals, by the nature of their operation, may cross various international boundaries and as a result, their performance will be required to satisfy the often differing regulations of each of these areas.

Additionally the value chain does not fit a standard format for the way in which it is implemented. Actors in this chain may participate in one area of the chain by supplying a single component or cover multiple areas by providing turn-key solutions. Ultimately, the responsibility falls on the actor assuming the system integrator role to qualify terminal performance for compliance with the regulatory requirements. In this role the system integrator will either, (i) rely on performance data that has been independently validated at the sub-system level and conduct a top level qualification at the system level or (ii), procure the various unqualified subsystem components and undertake all qualification tests at the full system level.

A customer or end user (defined as the entity utilizing the services of a satellite link) may purchase service directly from the satellite operator or via a value added reseller (VAR) or system integrator. The boundaries between each of these entities are often blurred and may involve one entity participating at different levels and in multiple environments.

The value chain has also seen the introduction of new technologies that are designed to best suit a particular market sector. An example would be the relatively new UK based company *Phasor Solutions* which has developed a product line for high speed SOTM terminals for the airborne, high speed rail as well as land and maritime platforms. A news release announced the successful operational test of Phasor Solution's, flat, electronically steered antenna array. The primary applications are well suited to SOTM for trains, planes, yachts & UAVs.

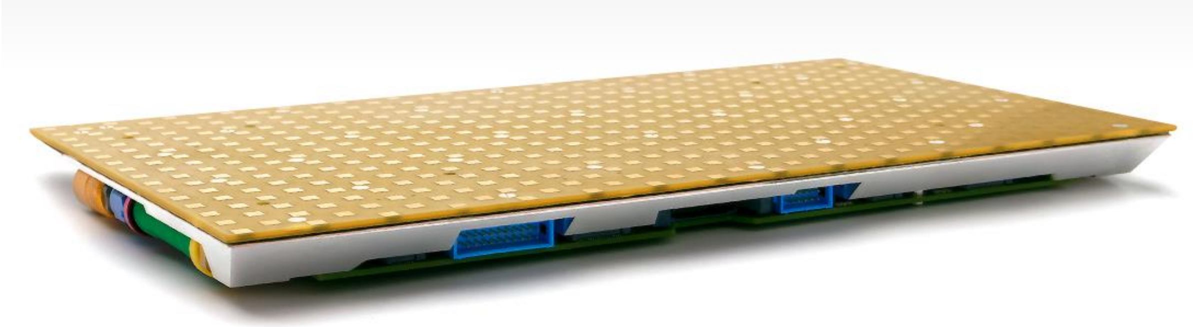


Figure 2: Phasor Solutions flat panel antenna

Other novel technologies have been introduced by *Thinkom* and *Kymeta*. The examples cited above typify the technologies that are being employed for the SOTM market. They utilize traditional solutions as well as emerging technologies.
The common threads that connect each of these technologies and entities together are the satellite operator specifications, ITU-R specifications and

national (country specific) regulations. These factors together with the performance validation procedures have the greatest impact on the time required to introduce new products to the market as well as the price for consumers purchasing SOTM equipment.

Figure 3 illustrates the various entities in the SOTM supply chain and their interactions. This framework applies across all of the vertical SOTM products and services. Figure 3 presents a clear identification of the various roles and transaction points. It shows the primary factors controlling the value chain. These are:

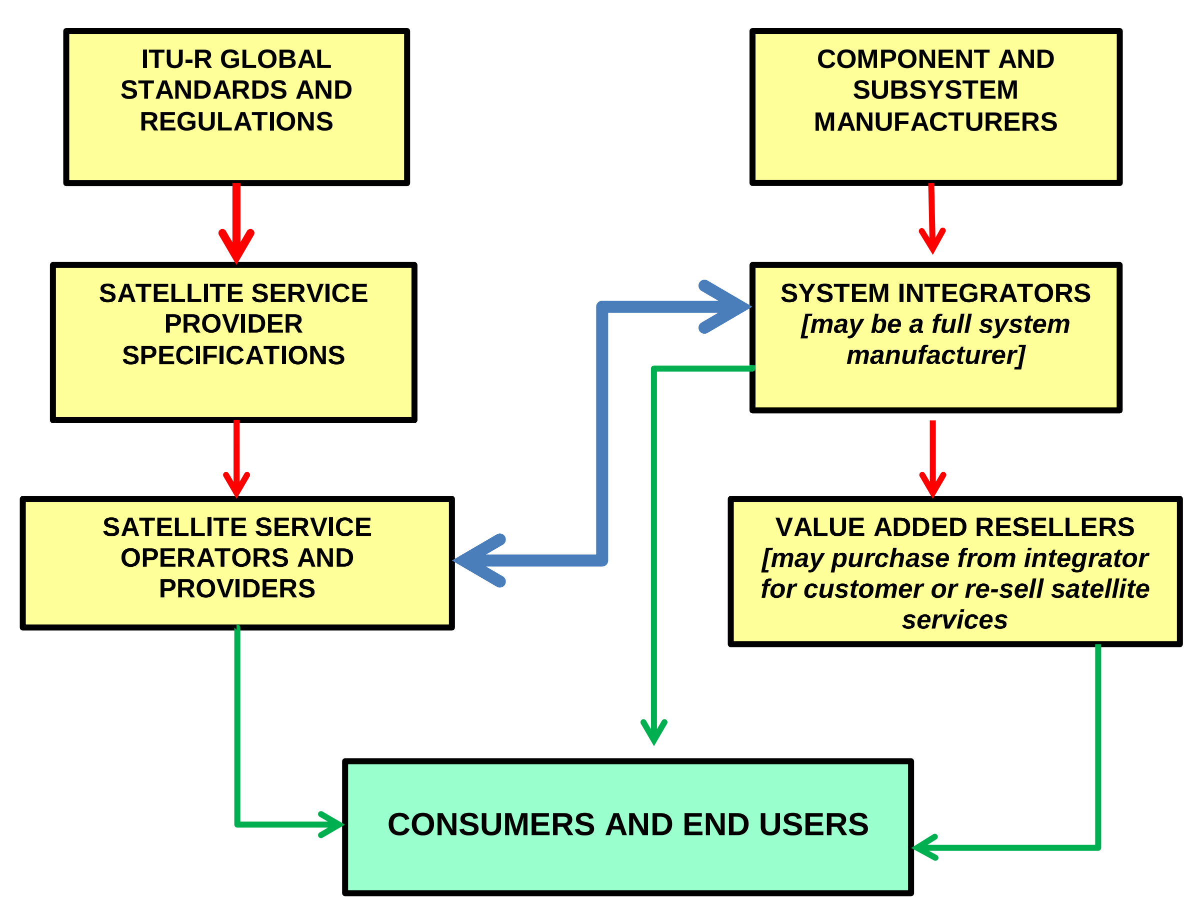
1. The ITU-R regulations. At the global level all SOTM products have to comply with the ITU-R regulations and standards. These should be considered as defining the minimum performance standards for SOTM terminals.
2. Below the ITU-R regulations are the specifications imposed by the various satellite operators. The satellite operator specifications may call for higher performance standards than the ITU-R regulations however they cannot call for more relaxed performance. A sub-group of the GVF was created to identify minimum performance specifications that would be accepted by all of the major satellite operators. Included in this group are Eutelsat, Intelsat, AsiaSat, SES and Inmarsat. The recommendations from this group were released but cannot be discussed openly as each of the participants is under NDA restrictions.

   Ultimately, the satellite operator and other regulatory performance requirements will have the greatest influence on the value chain. It has been reported by several manufacturers that the over-specification in some areas has had significant impact on the time to develop and qualify new products as well as on the final cost to consumers. One goal of the ESA study will be to carefully identify these concerns from the manufacturing sector and balance them against the performance specifications required by the satellite operators.

3. From the manufacturing side of the equation, the value chain provides several paths to market for various products. At the lowest level a manufacturer may elect to concentrate on the production of specific components or subsystems. Hardware at this level cannot be qualified to satisfy the full system requirements for and SOTM terminal. It therefore falls on a system integrator to “marry” all of the required components together and qualify terminal performance to the satisfaction of a satellite operator. The integrator may rely on component testing by the component manufacturer in this instance but ultimately will have to conduct final system level tests. At the highest level, a manufacturer may undertake all production in house and conduct system level qualification tests accordingly. There have been some instances where the product qualification is undertaken by the satellite operator. Prime examples here would include the product qualification programs implemented by Inmarsat for its initial approval of vendor equipment for the new Global Xpress GX program.
4. With the satellite operators and key integrators working together, qualified SOTM terminals may have several paths to market. These could include:
    a. Sale from the integrator to end customer.
    b. Sale from an integrator to Value Added Reseller (VAR) who then contracts with a satellite operator and re-sells service. This option may be attractive for customers who recognize the service they need to purchase but do not necessarily have the in-house capability to maintain and operate the equipment.
    c. Purchase of qualified equipment from an integrator or approved equipment list issued by a satellite operator in which the end user interacts directly with the satellite operator for commissioning the service.

Repeating an earlier observation, each of the above paths to market involves the deployment of qualified equipment. The cost for product qualification will vary depending on <u>where the testing is undertaken</u>. Major integrators and manufacturers most often have in-house test facilities and are estimated to constitute approximately 70 % of the market. The smaller SOTM providers often referred to as “mom & pop” operations have to contract for the qualification test services. It has been reported in one instance that approximately 10% of the SOTM terminals submitted for qualification failed to meet satellite operator requirements.

Figure 3: The Value Chain Components



4.1.1 Land mobile

Land-based SOTM market sector: Table 1 represents the primary actors supporting land mobile SOTM activities. For convenience High Speed Rail SOTM has been included in this grouping. The table has been arranged to identify each company or organization and their place in the vertical chain manufacturer / system integrator, satellite service operator and value added reseller.

Key Companies & products: In interview process the Fraunhofer IIS / GVF team has not been able to make a definitive assessment by products and services for each of the actors. This is beyond the scope of the study. Sales information by product and category is frequently considered to be proprietary and an accurate breakout is further complicated when actors are involved at multiple levels in the supply chain. From the surveys we have conducted thus far, the anecdotal evidence appears to fit the 70 / 30 rule. This implies that the major actors account for approximately 70% of the goods and services to each market sector.

ARTES AO7913 Manufacturer Listing
LAND BASED SOTM FOCUS

Company Name	Country	Contact Made	Relevance	Sub-system -mfg	COTM VALUE CHAIN ACTORS				Comments
					Manufacturers Integrators		SSO's	VAR's	
					Land Mobile	HS Rail			
ACORDE	Spain	x	x	x	x	x			Leading European Mfg for HPA's & BUC's used in COTM applications
Actia Sodielec	France		?	x	x	x			HPA'a / Small deployable terminals / Inmarsat Gx Compatible.
AKD Communication	China	x	x	x	x				Manufacturer of COTM terminals SSPA's, BUC's & related COTM products.
BOEING	USA	x	x		x				Active in COTM. Check additional references (see comment) for ESA study.
Cobham UK	UK	x	x	x	x				Satcom antennas and terminals etc
EM Solutions	Australia	x	x	x	x				New COTM terminal hardware offerings.
EPAK	Germany	x	x	x	x			x	COTM Antennas
Eutelsat	France	x	x				x		Satellite Service Provider
General Dynamics	USA	x	x	x	x				CTO for GD. GVF Board member. Strong familiarity with dynamics of COTM
Gilat	Israel	x	x	x	x				Mfg of low profile COTM equipment relevant to ESA study.
Global-way Comm	China	x	x		x				COTM antenna terminals and tracking antennas for land and maritime platforms.
Harris	USA	x	x	x	x		x	x	Strong participant across COTM Value Chain
iDIRECT	UK				x	x			Dennis Sutherland (see comment) interfaces with the GVF
iDirect	Various	x	x	x	x				Modems
iMAR	Germany				x				Stabilized Platforms for antennas etc.
Inmarsat	UK	x	x		x		x		Sattelite Service & equipment provider.
INTELSAT	USA	x	x				x	x	Satellite Service Provider
KYMETA	USA	x	x	x	x				Novel COTM tracking solution for COTM products.
L-3	USA	x	x		x		x		Major player in US COTM market.
LUSO	UK	x	x						Aerospace Systems
MOST	Israel	x	x	x	x				COTM products. Ku & Ka band products.
ND Satcom	Germany	x	x	x	x				System Integrator
Newtec	Belgium	x	x	x					Satellite Terminals / Modems etc
Norsat	Canada	x	x	x					Supplier of LNA / LNB's and related equipment used in COTM products.
PHASOR	UK	x		x	x	x			Low profile phased array Ku & Ka band antennas for COTM applications.
SATPRO	China	x	x	x	x				COTM terminals.
SEATEL / Cobham	UK				x				Maritime mobile terminals
Sematron UK	UK	x	x	x	x			x	Distributor Integrator SATCOM Terminals
SES	Lux	x	x				x		Satellite Service Provider
SpaceCom	Denmark								Mechanical tracking systems for Satcom antennas
TriaGnoSys	Germany								Mobile Communications, Land/Sea/Air

Table 1: Key elements of the land mobile SOTM market

4.1.2 Maritime

Maritime SOTM market sector: Table 2 identifies the primary actors supporting maritime SOTM activities. The table has been arranged to identify each company or organization and their place in the vertical chain manufacturer / system integrator, satellite service operator and value added reseller

Key Companies & products: In interview process the Fraunhofer IIS / GVF team has not been able to make a definitive assessment by products and services for each of the actors. This is beyond the scope of the study. Sales information by product and category is frequently considered to be proprietary and an accurate breakout is further complicated when actors are involved at multiple levels in the supply chain. From the surveys we have conducted thus far, the anecdotal evidence appears to fit the 70 / 30 rule. This implies that the major actors account for approximately 70% of the goods and services to each market sector.

Overlap: The study shows overlap where similar products are sold to each market segment. Likewise the operators support each of these areas with perhaps Inmarsat having increased focus on the maritime and airborne markets.

ARTES AO7913 Manufacturer Listing
MARITIME BASED SOTM FOCUS

Company Name	Country	Contact Made	Relevance	Sub-system -mfg	COTM VALUE CHAIN ACTORS: Manufacturers Integrators – Maritime	SSO's	VAR's	Comments
ACORDE	Spain	x	x	x	x			Leading European Mfg for HPA's & BUC's used in COTM applications
Actia Sodielec	France		?	x	x			HPA'a / Small deployable terminals / Inmarsat Gx Compatible.
AKD Communication	China	x	x	x	x			Manufacturer of COTM terminals SSPA's, BUC's & related COTM products.
BOEING	USA	x	x		x			Active in COTM. Check additional references (see comment) for ESA study.
Cobham UK	UK	x	x	x	x			Satcom antennas and terminals etc
EPAK	Germany	x	x	x	x		x	COTM Antennas
Eutelsat	France	x	x			x		Satellite Service Provider
Gilat	Israel	x	x	x	x			Mfg of low profile COTM equipment relevant to ESA study.
Global-way Comm	China	x	x	x	x			COTM antenna terminals and tracking antennas for land and maritime platforms.
Glomex	Italy			x	x			Maritime Mobile antennas etc.
Harris	USA	x	x	x		x	x	Strong participant across COTM Value Chain
iDirect	Various	x	x	x	x			Modems
iMAR	Germany			x	x			Stabilized Platforms for antennas etc.
IMST	Germany			x	x			Antenna Design, various
Inmarsat	UK					x		Sattelite Service & equipment provider.
Intellian	USA	x	x	x	x			Maritime COTM terminals.
INTELSAT	USA	x	x			x		Satellite Service Provider
KNS	Korea	x	x	x	x			Maritime COTM products
KYMETA	USA	x	x	x	x			Novel COTM tracking solution for COTM products.
L-3	USA	x	x		x	x		Major player in US COTM market.
LUSO	UK	x	x	x	x			Aerospace Systems
Micro Advanced Comms	Italy				x			Maritime mobile terminals
Navisystem	Italy				x			Maritime Mobile antennas etc.
ORBIT	Israel	x	x	x	x			Maritime mobile terminals
PHASOR	UK	x		x	x			Low profile phased array Ku & Ka band antennas for COTM applications.
RADIO MARINE S.p.A	Italy				x			Maritime mobile terminals
SEATEL / Cobham	UK	x	x	x	x			Maritime mobile terminals
SES	Lux	x	x			x		Satellite Service Provider
SITEP Italia Spa	Italy				x			Maritime mobile terminals
STENA	UK	x	x				x	Maritime & ship services provider
Thrane & Thrane	Denmark				x			Maritime Mobile antennas etc.
TriaGnoSys	Germany				x			Mobile Communications, Land/Sea/Air
Viasat	USA		x	x	x			Maritime terminals // Satcomhardware

Table 2: Key elements of the maritime SOTM market

4.1.3 Aeronautical

General: The primary divisions for the aeronautical SOTM market continue to follow the groupings identified in Figure 3 presented earlier. The same general interfaces exist for each of the value chain sectors and the international ITU-R regulations together with those imposed by the satellite operators and regional regulators dominate the market and drive product complexity and cost. Unlike the land mobile and maritime SOTM markets, the airborne sector generally requires light weight, low drag solutions. Solutions being explored by industry favor advanced antenna designs (conformal electronically scanned arrays for example) which in turn introduce requirements for more complex testing and product qualification. These additional features will distinguish products most suited to the airborne environment from those supplied to the land mobile and maritime SOTM markets.

Key Companies & products: In interview process the Fraunhofer IIS / GVF team has not been able to make a definitive assessment by products and services for each of the actors. Actors in this (as well as the other market sectors) range from those who specialize in the design and production at the component level, to full system integrators who may either (i), purchase components at the subsystem level and combine these in to a turnkey solution or (ii), execute production using 100% in-house resources and facilities. The industry imposed regulations and specifications imply that product performance has to be qualified at multiple levels and the question is where in the value-chain these activities take place. This is beyond the scope of the study.

Sales information by product and category is frequently considered to be proprietary and an accurate breakout is further complicated when actors are involved at multiple levels in the supply chain. From the surveys we have conducted thus far, the anecdotal evidence appears to fit the 70 / 30 rule. This implies that the major actors account for approximately 70% of the goods and services to each market sector.

Overlap: The study shows overlap where similar products are sold to each market segment. Likewise the operators support each of these areas. Again Inmarsat is seen having increased focus on the maritime and airborne market sector

Fraunhofer IIS

GVF Satellite. Solutions. The World.

ARTES AO7913 Manufacturer Listing
AIRBOURNE BASED SOTM FOCUS

Company Name	Country	Contact Made	Relevance	Sub-system -mfg	COTM VALUE CHAIN ACTORS: Manufacturers Integrators – Airbourne	SSO's	VAR's	Comments
BOEING	USA	x	x		x			Active in COTM. Check additional references (see comment) for ESA study.
Eutelsat	France	x	x			x		Satellite Service Provider
Global Eagle Entertainment		x	x				x	Aditya Chatterjee, Chief Technical Officer
GoGo	Spain	x	x				x	Greg Oliveau
iDirect	Various	x	x	x	x			Modems
Inmarsat	UK					x		Sattelite Service & equipment provider.
INTELSAT	USA	x	x			x		Satellite Service Provider
KYMETA	USA	x	x	x	x			Novel COTM tracking solution for COTM products.
Panasonic		x	x	x	x			David Bruner. VP Services
PHASOR	UK	x		x	x			Low profile phased array Ku & Ka band antennas for COTM applications.
QEST					x			Airborne satcom antennas [**Q**uantum**E**lectronic**S**ys**T**ems]
Row44			x				x	TBD
SES	Lux	x	x			x		Satellite Service Provider
SIS Live	UK						x	Satellite uplinks, services and antennas.
SkyTech	Italy/UK/US	x	x	x	x		x	SkyTech excellent COTM company for airbourne products. Strong candidate.
TECOM	USA/UK	x	x	x	x			Airbourne COTM products.
Thales	France							Aerospace // Diverse product manufacturer
TriaGnoSys	Germany				x			Mobile Communications, Land/Sea/Air
UltiSat	USA	x	x	x	x			Some airborne COTM.
Ultra Gigasat		x	?				x	John Dinithorne
Visilink		x	?				x	Colin wood

Table 3: Key elements of the airborne SOTM market

4.2 Collection of Product Information:

A number of entrants in the lists presented in Section 4.1 were contacted during different events, exhibitions and conferences, e.g. Satellite, CABSAT or via direct calls. Their websites were also visited where product datasheets and other relevant information were extracted and analyzed.

Some of the actors do not offer product specifications in a format which can be downloaded (e.g. Global-way and Satpro). Therefore there are no corresponding datasheets included however, their products have been considered in the analysis.

The actors include also system integrators and value added resellers who are offering complete SOTM solutions (e.g. Harris, Hughes and Ultisat)

An Appendix with the datasheets collected during the process of WP1200 was submitted as a deliverable of the project.

The comprehensive analysis w.r.t. Antennas, Modems and Services is covered in the scope of WP2100 (Current buying process) as discussed in Section 5.1.

5. Current Buying Process

In Task 2 of this project, the current SOTM buying process was analysed w.r.t two aspects:

1. The main performance parameters of a SOTM product: performance metrics and how to test them were extracted out from the different product specifications and datasheets.
2. The problems and inefficiencies: all wastes that negatively affect the different parts of the value chain were sorted out and discussed separately.

5.1 Product Analysis

The datasheets collected in the scope of WP1200 were analyzed. The products were separated w.r.t. environment type: land mobile, maritime and aeronautical. If the list entrant provides products/solutions for different environments, the same datasheet is considered in the analysis of the different corresponding environments.

Many manufacturers and system integrators focus in the datasheets on antenna specifications and do not specify clearly what modem is used or they want to keep it transparent. For that reason, the analysis of modems and services were introduced separately.

In the analysis of the products/services, two main aspects were considered:

1. Technical specifications: of the Out-Door Unit (ODU) and (if available) the In-Door Unit (IDU).
2. Conformity to standards: if available, information about Standards or Type Approvals stated by the manufacturer/integrator e.g. antenna pointing performance, etc.

5.1.1 Land mobile / High Speed Railway

Table 4 summarizes the analysis of the products available for the land mobile / HS Railway segment of the SOTM market.

Whether it is an internal development or an integrated terminal, the product name is specified in a separate column. A single entrant might offer more than one product (e.g. a dish antenna and a panel array) or a series of enhanced single product (e.g. same product but with enhanced functionalities).

In the set of columns about the product technical specifications, all available information about the IDU and ODU are listed. The specifications include:

1. Antenna specifications: type, diameter, gain and polarization
2. Frequency band
3. Block Up-Converter (BUC) specifications: EIRP
4. If available, tracking performance specifications: tracking rates, supported speed and terrain
5. If available, modem specifications: type and data rates

The column “conformity with standards” carries information related to standards and how the product is in conformance with them.

The column “services” carries information related to the type of services that the entrant provides.

company	Value Chain Actors				Product(s)	environment	band	Tech. Specs.									Conformity with standards	Supported Speed	Pointing error	Services
								Antenna and BUC						Modem						
	Manuf-acturer	Integrator	SSO	VAR				type	diameter	Pol	tracking rates	Gain	EIRP	type	data rate					
															Uplink	downlink				
ACORDE	X	X			SOTM products	No specs	http://www.acorde.com/english/satelite-y-radiofrecuencia-comunicaciones.php													Manufacturing / Integration
Actia Sodielec		X				LandMobile (Military)	Ka	dish	1-2.4 m								Inmarsat cooperation and Type approvals (Inmarsat Gx)			Broadband Comm / Defense
COBHAM	X	X			EXPLORER 9092H	LandMobile (Military)	Ku	panel		Linear with <25dB Xpol isol.	100 °/s vel. And 200°/s^2 Acc	36 dBi	50 dBW						<0.5 mitigated to <0.2	VideoConf. / Internet services
					SPITFIRE	LandMobile / Aero.	Ku	panel			400 °/s		44.5 dBW				ETSI EN 302 186 / Eutelsat M type approaved			
EM solutions	X	X			SAT_TRACKER	LandMobile	X	dish	60 cm	H/V		29 dB	41 dBW	-	-	-	field trials with the Australian Defence Force	100 km/h on highway & 40 km/h on off-road	<0.5° (<0.1 dB) [off-road]	civilian use in emergency services
						LandMobile	Ku	dish	60 cm	H/V		35 dB	46 dBW	-	-	-	field trials with the Australian Defence Force	100 km/h on highway & 40 km/h on off-road	<0.4° (<0.1 dB) [off-road]	
						LandMobile	Ka	dish	48 cm	RHCP/ LHCP		39.8 dB	47.5 dBW	-	-	-	field trials with the Australian Defence Force	100 km/h on highway & 40 km/h on off-road	<0.2° (<0.1 dB) [off-road]	
						LandMobile	Ka	dish	60 cm	RHCP/ LHCP		42.5 dB	50 dBW	-	-	-	field trials with the Australian Defence Force	100 km/h on highway & 40 km/h on off-road	<0.2° (<0.15 dB) [off-road]	
Eutelsat			X		Service provider															
General Dynamics	X	X			SOTM	LM, Maritime and Aeor.	Ku/Ka	dish/panel	43-60 cm	Linear -circular			45 -53 dBW				FCC VMES Compliant - ChurchvilleB certified	<100 km/h	<0.2° for 99%	Manufacturing for interoperable services
					1985	LandMobile	Ku	dish	98 cm	Linear		41 dBi					Eutelsat type approaved			
Gilat-RaySat		X			RaySat ER5000 Ku	LandMobile	Ku	panel		Linear	150 °/s	31 dBi	47 dBW	GLT1000						Integrator for military and civil apps
					RaySat ER5000 Ka	LandMobile	Ka	panel		Circular	150 °/s	36 dBi	52 dBW	GLT1000						
Global-Way		X			C2P	LandMobile	Ku	phased Array		Circular	80 °/s		52 dBW					120 km/h		Integrator for civil apps
					1.2M ANTENNA	LandMobile	Ku/Ka	dish	1.2 m	Linear/circular		41.7 dBi								
High Gain Antenna Co.	X				0.7 M Ship	Maritime	Ku	dish	70 cm	Linear		36 dBi					Intelsat type approved			Manufacturing
Hughes	X	X			HX COTM	LandMobile/HS Railway	Ku	dish/phased Array		Linear							Intelsat type approved / tested for harsh environments!!!			Integrated Broadband for Vehicles
Indra		X			X Band SOTM	LandMobile (Military)	X	dish/flat		Circular		30 dBi	>46 dBW			<2 Mb/s	Churchville B tested			Integration for tactical voice and data

company	Value Chain Actors				Product(s)	environment	band	Tech. Specs.									Conformity with standards	Supported Speed	Pointing error	Services
								Antenna and BUC						Modem						
	Manuf-acturer	Integrator	SSO	VAR				type	diameter	Pol	tracking rates	Gain	EIRP	type	data rate Uplink	data rate downlink				
Inmarsat			X		Service provider															
Intelsat			X		Service provider															
Kymeta	X					Landmobile /Maritime														Manufacturing for interoperable services
L3 Datron	X	X		X	FSS-4000-LC	LandMobile (Military)	Ku	dish	46 cm	Linear			45 dBW				Proven performance and reliability in theater			Manufacturing and Integration for Military apps
					FSS-4000-LC	LandMobile (Military)	Ka	dish	46 cm	circular			47 dBW				Proven performance and reliability in theater			
MOST-Sys	X				MOST-Ku	LandMobile	Ku	shaped reflector		Linear	150°/s and 300°/s^2	33 dBi	48 dBW							Antenna Manufacturing
					MOST-Ku	LandMobile	Ka	shaped reflector		circular - fixed	150°/s and 300°/s^2	40 dBi	51 dBW							
NDSatCom		X			SOTM	LandMobile	Products from Cohbam and Raysat													Terminal Integration
Phasor sol.	X				Phasor	LM, Maritime and Aeor.	Ku	phased array	1" height											Antenna Manufaturing
RFmicroTech	X				Ku-band flat	LM, Maritime and Aeor.	Ku	panel	110 cm x 5 cm	Linear			42 dBW @25° El				ETSI & FCC satellite regulation compliant			Antenna Manufaturing
SatCom International		X		X	ORTeS	LandMobile	Ku	shaped reflector		Linear							Intelsat type approved			
Satpro	X				P900	LandMobile	Ku	dish	113 cm	Linear	100°/s0	40 dBi							<0.2°	Antenna Manufaturing
SES			X		service provider												Inmarsat, Thuraya ...			
SquireTech		X			MR 100/300/500/600	LandMobile								iDirect Infiniti 5000						Integration for emergency apps
Thinkom	X				ThinSat 300	LandMobile	Ku	panel		Linear			52 dBW				FCC 25.226 Approved for Highway speeds			Antenna Manufaturing
TTI	X				KU08A	LandMobile	Ku	panel		Linear	60°/s	31.5 dBi	42 dBW				Hispasat type approved			Antenna Manufaturing
Viasat	X	X			VMT-1220	LandMobile	Ku	panel		Linear			>44.5 dBW		1 Mb/s	10 Mb/s	operate within FCC and ITU regulatory guidelines for adjacent satellite interference.			Broadband IP access
						Airborne	Ku	dish		Linear	20°/s		>46 dBW				ITU/FCC compliant with spread spectrum interference mitigation			
WINEGARD	X					LandMobile	Ku	dish	20"	Linear										Antenna Manufaturing

Table 4: Land mobile Product / Performance listing

Analysis (Land mobile)

1. Antennas and frequencies (Land mobile)

The type of antennas and the frequencies for each entrant were listed.

The results were analyzed in terms of statistics as follows:

- Antenna Type:

  ~48% of the entrants use/produce reflector antennas only
  ~23% use/produce Panel/Phased Array antennas
  ~29% use/produce both reflector and Panel/Phased Array antennas

- Frequency:

  ~6% are operating in Ka-band only
  ~61% are operating in Ku-band only
  ~33% are operating in Ka-/Ku-bands

2. BUC and tracking performance (Land mobile)

The Effective Isotropic Radiated Power (e.i.r.p) depends on the gain of the antenna and on how powerful the BUC is. The EIRP values range from 41dBW to 53dBW.

Some entrants specify the maximum rates that their tracking unit can follow. The rates range between 60°/s to 150°/s and accelerations up to 300°/s^2. Although, the maximum affordable angular rate and acceleration are not stated in all datasheets, they are seen as very important parameters. At Fraunhofer IIS, several terminal tests have been carried out. In some cases the test of the terminal on a specific track was not successful because the maximum affordable angular rate was exceeded.

3. Services (Land mobile)

A wide range of services are provided by the entrants. The services provided can be divided to:

1. System related: sub-system manufacturing, system integration or satellite system operation
2. Application related: broadband communication, IP bridging, military surveillance, emergency responding, etc.

4. Conformity with standards (Land mobile)

It is either stated that the product is in conformance with some standard (recommendation/Norm), or that it has a successful trial in one or more of the type approvals, or in few cases it is explicitly stating the maximum pointing error of the antenna.

In the following, we summarize the main points (concerning off-axis emissions and tracking performance) in the land mobile related standards and type approvals.

Recommendations and Norms (Land mobile)

- **MIL-STD-188-164B (Ku/Ka)**
  - **Ku**
    - Same requirements as IESS-601 from Intelsat
  - **Ka**
    - Stating the 29-25log(Theta) gain mask and e.i.r.p. mask. The compliance to this mask has to be tested.
    - The maximum pointing error of the antenna is declared specified in terms of power loss (dB scaling).
    - How the tests are performed or in which Testing Entity is left open for the applicant.

- **ETSI EN 302 977 (VMES at Ku)**
  - Stating an e.i.r.p. mask for the co-/cross-polar patterns. The compliance to this mask has to be tested.
  - The radiation patterns (E-/H- planes) as well as the antenna maximum gain have to be measured.

- The maximum pointing error of the antenna is declared by the applicant. The commitment to this limit has to be tested.
- How the tests are performed or in which Testing Entity is left open for the applicant.

- **FCC 25.226 (VMES at Ku)**
  - The e.i.r.p. mask is stricter (Narrower) than the ones defined by ETSI. The compliance to this mask has to be tested.
  - A maximum pointing error of 0.2° is to be maintained.
  - The maximum pointing error of 0.2° can be exceeded as long as the e.i.r.p. limits are preserved. The new maximum pointing error has to be declared by the applicant.
  - The VMES has to demonstrate the ability to cease transmission if the pointing error exceeds 0.5° for 100 milliseconds.
  - The VMES has to have the ability to detect any excess pointing error and has to demonstrate the ability to cease transmission within 100 milliseconds.

- **ITU-R S.1857 (Ku)**
  - An e.i.r.p. mask is stated. The compliance to this mask has to be tested.
  - Statistically modelling the motion-induced pointing error based on measurements on different representative drive paths. The CDFs of the pointing error are depicted.
  - A method to assess the Adjacent Satellite Interference (ASI) caused by vehicle movement is proposed. The method uses two fixed earth stations receiving from the target as well as the adjacent satellite. Based on the measured power levels and the a-priori knowledge of the antenna radiation pattern, the ASI can be assessed.

- **ETSI EN 302 448 (Earth Station on Trains EST at Ku)**
  - The e.i.r.p. mask for the Ka-band is similar to the one in the **ETSI EN 302 977 Ku Norm**. The compliance to this mask has to be tested.

    - The radiation patterns (E-/H- planes) as well as the antenna maximum gain have to be measured.
    - The maximum pointing error of the antenna is declared by the applicant. The commitment to this limit has to be tested.
    - How the tests are performed or in which Testing Entity is left open for the applicant.

  - **ETSI EN 303 978 (ES on Mobile Platforms at Ka)**
    - Mobile platforms are defined as trains, vessels, aircraft or any non-stationary vehicles.
    - The e.i.r.p. mask for the Ka-band is narrower than the one in the **ETSI EN 302 977 Ku Norm**. The compliance to this mask has to be tested.
    - The radiation patterns (E-/H- planes) as well as the antenna maximum gain have to be measured.
    - The maximum pointing error of the antenna is declared by the applicant. The commitment to this limit has to be tested.
    - How the tests are performed or in which Testing Entity is left open for the applicant.

  - **FCC 25.138 (Blanket Licensing provisions at Ka)**
    - The e.i.r.p. mask is generally wider than the ones defined at Ku.
    - No pointing accuracy requirements stated.

- ***General Notes:***
  - In general, recommendations and norms do not state how to test systems against the proposed limits. In most of the cases it is left ***open*** for the applicant.

Since recommendations and norms leave the applicant to decide how to test the SOTM terminal against the specified limits, satellite system operators (SSO) define Type Approvals. In a Type Approval, the SSO states more specifically how the antenna will be tested.

Type Approvals are in general specified by the SSOs. In other words, each SSO has his own Type Approval. However, since Type Approvals are referring to the same recommendations and norms, they are quite similar.

For a SOTM terminal to be widely approved, the applicant has to apply for many Type Approvals which are similar. This is time consuming, cost inefficient and negatively affecting the whole SOTM value chain.

In the following, we summarize the existing Type Approvals which were stated by the entrants.

Type Approvals:

- EESS502 with ESOG 120 from Eutelsat
  - Antenna radiation patterns in different planes (GSO and its parallels) for different antenna skew angles have to be measured.
  - The e.i.r.p. mask is starts at a point which depends on the antenna diameter and the orbital separation of the adjacent satellite.
  - Antenna gain masks are also defined. 2D Gain overshoots, where the antenna gain exceeds the mask is to be depicted.
  - Authorized Testing Entities (ATE) are generally defined by the applicant and witnessed by Eutelsat.

- IESS-601 from Intelsat
  - Tests to prove compliance with the ITU-R S.1857 norm
  - SSOG 210 for antenna verification testing.
  - SSOG 200 Intelsat type approval.

- Type approvals by the Global VSAT Forum (GVF 101/105)
  - The 29-25log(Theta) gain mask is specified. This mask is similar to the one defined by Eutelsat (EESS502).

        - The two-satellite approach specified in the ITU-R S.1857 recommendation is used to assess the antenna pointing error.
        - In the scope of the ESA ARTES 5.1 4000103870/11/NL/NR Project, the GVF-105 document is to be extended by recommendations for the standard motion profiles which can be used to test the SOTM Terminal.

    - Inmarsat type approvals
        - The Global Xpress GX type approval program

Statistical Analysis (Land mobile)

From the land mobile entrants list, the following statistics can be derived:

- ~40% do not state anything about certifications
- ~12% state that they comply with ETSI/FCC norms but without any details under which motion conditions they tested it
- ~ 36% of the manufacturers perform type approvals
    - by Eutelsat /Intelsat/Inmarsat/Hispasat
    - nothing mentioned about motion profiles – only turning tables mentioned!!)
- ~12% define the motion track which they used e.g. churchvilleB (not for all products)
- ~16% specify the tracking accuracy of their SOTM terminals
    - Only 8% specify under which conditions or at what limits (e.g. churchvilleB, 99% of the cases, up to 70°elevation..)

General Notes **(Land mobile)**

- The lack of a standard type approval leads to:
  - non standardized products as shown in the Statistical Analysis (40% do not specify anything about certifications)
  - Cost/time inefficiencies due to running many similar Type Approvals for the same product line.
- Standard reproducible motion profiles are overall not specified
  - Non-standard but frequently used motion tracks e.g. ChurchvilleB and Millbrook PG.

It can be seen how analyzing the SOTM value chain helps showing the need for a standardized testing methodology or Type Approval.

5.1.2 Maritime

Table 5 summarizes the analysis of the products available for the maritime segment of the SOTM market.

Table 5 is structured in the same way as Table 4. Fields with frequency, technical specifications, conformity with standards and services are included.

The number of entrants in the maritime list is more than that for the land mobile case. This reflects the reality in the SOTM market where maritime SOTM has a larger share of the market than land mobile SOTM.

company	Value Chain Actors				Product(s)	environment	band	Tech. Specs.								
								Antenna and BUC						Modem		
	Manuf-acturer	Integrator	SSO	VAR				type	diameter	Pol	tracking rates	Gain	EIRP	type	data rate	
															Uplink	downlink
C2SAT	X				C2SAT Ku100MIL	Maritime	Ku	dish	1.45 m	Linear		42 dBi	59 dBW			
COBHAM	X	X			5009	Maritime	Ku	dish	1.2 m	Linear						
EPAK	X	X		X	DSi9 Ku	Maritime	Ku	dish	90 cm	H/V	30 °/s	-	44 dBW	-		8 Mb/s
					DSi9 Ka	Maritime	Ka	dish	90 cm	RHCP/ LHCP	30 °/s	-	44 dBW	viasat	4 Mb/s	10 Mb/s
Eutelsat			X		Service provider											
General Dynamics					SOTM	LM, Maritime and Aeor.	Ku/Ka	dish/Panel	43-60 cm	Linear -circular			45 -53 dBW			
Global-Way		X			S2P	Maritime	Ku	phased Array		Circular	60 °/s		52 dBW			
					S4	Maritime	Ku	dish	45 cm	Circular	70 °/s		49 dBW			
Harris			X	X	AN/WSC-6(V)9	Maritime	Ka	dish	1.5 m	Circular			57 dBW		4 Mb/s	
					CBSP ULV	Maritime	Ku	dish	1.3 m	Linear			58.8 dBW			
High Gain Antenna Co.	X				0.7 M Ship	Maritime	Ku	dish	70 cm	Linear		36 dBi				
iDirect		X		X	integrator	Maritime										
IMST	X				Antenna designs											
Intellian	X	X			v60G	Maritime	Ku	dish	23.6 cm	Linear		38 dBi				
					GX60	Maritime	Ka	dish	25.6 cm	circular		44 dBi				
					V100	Maritime	Ku	dish	103 cm	Linear		41.6 dBi				
Inmarsat			X		Service provider											

company	Product(s)	Conformity with standards	Supported Speed	Pointing error	Services
C2SAT	C2SAT Ku100MIL	US Military standards for vessels participating in sea warfare and defence		0.1°	Manufacturing
COBHAM	5009	Eutelsat type approved		<0.2°	VideoConf. / Internet services
EPAK	DSi9 Ku				Internet services and applications
	DSi9 Ka				
Eutelsat	Service provider				
General Dynamics	SOTM	FCC VMES Compliant - ChurchvilleB certified	<100 km/h	<0.2° for 99%	Manufacturing for interoperable services
Global-Way	S2P				Integrator for civil apps
	S4				
Harris	AN/WSC-6(V)9	Intelsat IESS-601			Wideband comm for tactical and civil apps
	CBSP ULV	Intelsat IESS-601			
High Gain Antenna Co.	0.7 M Ship	Intelsat type approved			Manufacturing
iDirect	integrator				Internet broadband comms
IMST	Antenna designs				
Intellian	v60G			<0.2°	highspeed comm apps of Inmarsat GX
	GX60	Inmarsat type approved		<0.2°	
	V100	Eutelsat type approved w/ <0.4° pointing error		<0.2°	
Inmarsat	Service provider				

company	Value Chain Actors				Product(s)	environment	band	Tech. Specs.									Conformity with standards	Supported Speed	Pointing error	Services
	Manuf-acturer	Integrator	SSO	VAR				Antenna and BUC						Modem						
								type	diameter	Pol	tracking rates	Gain	EIRP	type	data rate					
															Uplink	downlink				
Intelsat			X		Service provider															
JOTRON	X				B85 Ku/Ka	Maritime	Ku/Ka	dish	85 cm	Linear -circular			48.6 -50.8 dBW				Eutelsat/Intelsat type approved		<0.3°	Manufacturing for Maritime
Kns-Kr	X				SuperTrack S-Series	Maritime	Ku	dish	45 cm	Linear	>90°/s		>48 dBW							Manufacturing for Maritime
					SuperTrack K-Series	Maritime	Ku	dish	39 cm	Linear	<50°/s		>49 dBW							
					SuperTrack Z-Series	Maritime	Ku	dish	61 cm	Linear	>90°/s	37 dBi					Intelsat type approved / avanti type approved (ETSI EN 303-978 for Ka)			
					SuperTrack A-Series	Maritime	Ku	dish	61 cm	Linear	>90°/s	36 dBi					certified according to ETSI EN 302 340			
Kymeta	X					LandMobile/Maritime														Manufacturing for interoperable services
Mitsubishi	X				Ku-mate	Maritime	Ku	dish	1 m	Linear			49 dBW				Conforming to Eutelsat EESS502		<0.2°	Antenna manufacturing
Navisystem		X			MST135P	Maritime	Ku	dish	135 cm	Linear	36°/s	43 dBi	>40 dBW				Eutelsat-Type Approved according EESS 502 Standard M			
Norsat	X				MarineLink Com10	Maritime	Ku	dish	100 cm	Linear	90°/s	40 dBi			512 KB/s	2 Mb/s				Antenna manufacturing
ORBIT	X				OceanTRx™ 4 /Ku	Maritime	Ku	dish	1.15 m	Linear			54 dBW w/ 16W BUC				ITU, FCC, ETSI, EutelSat, IntelSat, ANATEL	10°/s ship turning rate		Antenna Manufacturing
					OceanTRx™ 4 /Ka	Maritime	Ka	dish	1.15 m	Circular			57 dBW w/ 10W BUC				ITU, FCC, ETSI, EutelSat, IntelSat, ANATEL	10°/s ship turning rate		
					AirTRx	Airborne	Ku/Ka	dish	36-38 cm	Linear -circular	40°/s		45 -50 dBW				ITU R S. 728 and FCC 25.222 for Ku -- ITU R S. 524 and FCC 25.138 for Ka		<0.2°	
Phasor sol.	X				Phasor	LM, Maritime and Aeor.	Ku	phased array	1" height											Antenna Manufaturing
Radio-marine		X			Radiomarine BroadBand80	Maritime	Ku	dish	80 cm	Linear						2 Mb/s				

company	Value Chain Actors				Product(s)	environment	band	Tech. Specs.									Conformity with standards	Supported Speed	Pointing error	Services
	Manuf-acturer	Integrator	SSO	VAR				Antenna and BUC						Modem						
								type	diameter	Pol	tracking rates	Gain	EIRP	type	data rate					
															Uplink	downlink				
RFmicroTech	X				Ku-band flat	LM, Maritime and Aeor.	Ku	panel	110 cm x 5 cm	Linear			42 dBW @25° El				ETSI & FCC satellite regulation compliant			Antenna Manufaturing
SEATEL	X	X			4009	Maritime	Ku	dish	1 m			40.6 dBi					Eutelsat type approved			Manufaturing / Integration
			X																	
SES					service provider												Inmarsat, Thuraya ...			
SITEP Italia	X				Automatic VSAT	Maritime / Military	Ku	dish	80 cm	Linear		37.9 dBi								Antenna Manufaturing
SkyTech	X	X			VFlat Ku/Ka	Maritime	Ku/Ka	horn array		Linear -circular			<42 dBW				conforming FCC and Eutelsat EESS502 (in progress)		<0.2°	Manufaturing / Integration
					BB75	Maritime	Ka	dish	75 cm	circular							Conforming to Eutelsat EESS502		<0.2°	
					BB105	Maritime	Ku/Ka	dish	105 cm	Linear -circular			<50 dBW				FCC 25.222, 25.138, Telenor, Eutelsat EESS502 (in progress)		<0.2°	
Thrane & Thrane /COBHAM		X			Sailor 800	Maritime	Ku	dish	83 cm	Linear		40 dBi					Eutelsat type approved			Internet broadband comms
UltiSat		X				Maritime	http://www.ultisat.com/da/content/maritime													Integration for Military apps

Table 5: Maritime Product / Performance listing

Analysis (Maritime)

1. Antennas and frequencies (Maritime)

The type of antennas and the frequencies for each entrant were listed.

The results are analyzed in terms of statistics as follows:

- Antenna Type:

  ~80% of the entrants use/produce reflector antennas only
  ~8% use/produce Panel/Phased Array antennas
  ~12% use/produce both reflector and Panel/Phased Array antennas

- Frequency:

  ~No entrants are operating in Ka-band only
  ~56% are operating in Ku-band only
  ~44% are operating in Ka-/Ku-bands

2. BUC and tracking performance (Maritime)

The Effective Isotropic Radiated Power (e.i.r.p) depends on the gain of the antenna and on how powerful the BUC is. The EIRP values range from 42dBW to 59dBW. The values are higher than in the land mobile environment since the maritime antennas can be relatively bigger.

Some entrants specify the maximum rates that their tracking unit can follow. The rates range between 30°/s to 90°/s. The rates are lower compared to the land mobile capabilities since the motion dynamics are generally lower in the maritime environment.

3. Services (Maritime)

The same categories of services in the land mobile market segment apply for maritime. The services provided can be divided to:

1. System related: sub-system manufacturing, system integration or satellite system operation
2. Application related: broadband communication, IP bridging, military surveillance, emergency responding, etc.

4. Conformity with standards (Maritime)

Same as in the land mobile environment, it is either stated that the product is in conformance with some standard (recommendation/Norm), or that it has a successful trial in one or more of the type approvals, or in few cases it is explicitly stating the maximum pointing error of the antenna.

In the following, we summarize the main points (concerning off-axis emissions and tracking performance) in the maritime related standards and type approvals.

Recommendations and Norms (Maritime)

- **ETSI EN 302 340 (Earth Stations on Vessels ESV at Ku)**
  - An e.i.r.p. mask similar to the one in the **ETSI EN 302 977 Norm (VMES at Ku)** is stated for the co-/cross-polar patterns. The compliance to this mask has to be tested.
  - The radiation patterns (E-/H- planes) as well as the antenna maximum gain have to be measured.
  - The maximum pointing error of the antenna is declared by the applicant. The commitment to this limit has to be tested.
  - How the tests are performed or in which Testing Entity is left open for the applicant.

- **FCC 25.222 (Earth Stations on Vessels ESV at Ku)**
  - The e.i.r.p. mask is stricter (Narrower) than the ones defined by ETSI. The compliance to this mask has to be tested.
  - The conditions are very much the same as in FCC 25.226 for VMES.
  - A maximum pointing error of 0.2° is to be maintained.
  - The maximum pointing error of 0.2° can be exceeded as long as the e.i.r.p. limits are preserved. The new maximum pointing error has to be declared by the applicant.
  - The VMES has to demonstrate the ability to cease transmission if the pointing error exceeds 0.5° for 100 milliseconds.

- The VMES has to have the ability to detect any excess pointing error and has to demonstrate the ability to cease transmission within 100 milliseconds.

- **ETSI EN 303 978 (ES on Mobile Platforms at Ka)**
  - Mobile platforms are defined as trains, vessels, aircraft or any non-stationary vehicles.
  - The e.i.r.p. mask for the Ka-band is narrower than the one **ETSI EN 302 340 (ESV at Ku)**. The compliance to this mask has to be tested.
  - The radiation patterns (E-/H- planes) as well as the antenna maximum gain have to be measured.
  - The maximum pointing error of the antenna is declared by the applicant. The commitment to this limit has to be tested.
  - How the tests are performed or in which Testing Entity is left open for the applicant.

- **FCC 25.138 (Blanket Licensing provisions at Ka)**
  - The e.i.r.p. mask is generally wider than the ones defined at Ku.
  - No pointing accuracy requirements stated.

On the other and, the Type approvals are operator dependent and the underlying procedures are similar for the different environments.

Statistical Analysis (Maritime)

From the maritime entrants list, the following statistics can be derived:

- ~36% do not state anything about certifications
- ~4% state that they comply with ETSI/FCC norms but without any details under which motion conditions they tested it
- ~ 56% of the manufacturers perform type approvals
  - by Eutelsat /Intelsat/Inmarsat/Hispasat
  - nothing mentioned about motion profiles – only turning tables mentioned!!)
- ~8% define the motion track which they used e.g. churchvilleB (not for all products)
- ~32% specify the tracking accuracy of their SOTM terminals
  - Only 12% specify under which conditions or at what limits (e.g. churchvilleB, 99% of the cases, up to 70°elevation..)

General Notes (Maritime)

- The lack of a standard type approval leads to:
  - non standardized products as shown in the Statistical Analysis (36% do not specify anything about certifications)
  - Cost/time inefficiencies due to running many similar Type Approvals for the same product line.
- Standard reproducible motion profiles are overall not specified
  - Non-standard but frequently used motion tracks e.g. ChurchvilleB and Millbrook PG.

It can be again seen how analyzing the SOTM value chain helps showing the need for a standardized testing methodology or Type Approval.

5.1.3 Aeronautical

Table 6 summarizes the analysis of the products available for the aeronautical segment of the SOTM market.

Table 6 is structured in the same way as Table 4 and Table 5 for the land mobile and the maritime environments, respectively. Fields with frequency, technical specifications, conformity with standards and services are included.

The number of entrants in Table 6 reflects the reality in the SOTM market where aeronautical SOTM is a new segment which is recently developing and seen as a potential source of benefit for the Satellite Communications industry.

company	Value Chain Actors				Product(s)	environment	band	Tech. Specs.									Conformity with standards	Supported Speed	Pointing error	Services
	Manuf-acturer	Integrator	SSO	VAR				Antenna and BUC						Modem						
								type	diameter	Pol	tracking rates	Gain	EIRP	type	data rate					
															Uplink	downlink				
COBHAM	X	X			SPITFIRE	LandMobile / Aero.	Ku	panel			12°/s - 24 °/s		44.5 dBW				ETSI EN 302 186 / Eutelsat M type approaved			VideoConf. / Internet services
Eutelsat			X		Service provider															
General Dynamics	X	X			SOTM	LM, Maritime and Aeor.	Ku/Ka	dish/panel	43-60 cm	Linear -circular			45 -53 dBW				FCC VMES Compliant - ChurchvilleB certified	<100 km/h	<0.2° for 99%	Manufacturing for interoperable services
					1985	LandMobile	Ku	dish	98 cm	Linear		41 dBi					Eutelsat type approaved			
Inmarsat			X		Service provider															
Intelsat			X		Service provider															
ORBIT	X				OceanTRx™ 4 /Ku	Maritime	Ku	dish	1.15 m	Linear			54 dBW w/ 16W BUC				ITU, FCC, ETSI, EutelSat, IntelSat, ANATEL	10°/s ship turning rate		Antenna Manufaturing
					OceanTRx™ 4 /Ka	Maritime	Ka	dish	1.15 m	Circular			57 dBW w/ 10W BUC				ITU, FCC, ETSI, EutelSat, IntelSat, ANATEL	10°/s ship turning rate		
					AirTRx	Airborne	Ku/Ka	dish	36-38 cm	Linear -circular	40°/s		45 -50 dBW				ITU R S. 728 and FCC 25.222 for Ku -- ITU R S. 524 and FCC 25.138 for Ka		<0.2°	
Phasor sol.	X				Phasor	LM, Maritime and Aeor.	Ku	phased array	1" height											Antenna Manufaturing
QEST	X					Airborne	Ku	horn array		Linear							FCC-compliant up to 35 degrees skew angle			Antenna Manufaturing
TECOM						Airbourne	Ku	dish		Linear	30°/s Vel and 30°/s^2 Acc	42 dBW							<0.2°	Antenna Manufaturing
						Airbourne	Ka	dish		Circular	30°/s Vel and 30°/s^2 Acc	46 dBW							<0.2°	
Viasat	X	X			VMT-1220	LandMobile	Ku	panel		Linear			>44.5 dBW		1 Mb/s	10 Mb/s	operate within FCC and ITU regulatory guidelines for adjacent satellite interference.			Broadband IP access
						Airborne	Ku	dish		Linear	20°/s		>46 dBW				ITU/FCC compliant with spread spectrum interference mitigation			
UltiSat		X			No specs	Airborne	Ku													Integration for Military apps

Table 6: Aeronautical Product / Performance listing

Analysis (Aeronautical)

1. Antennas and frequencies:

The type of antennas and the frequencies for each entrant were listed.

The results are analyzed in terms of statistics as follows:

- Antenna Type:

  ~38% of the entrants use/produce reflector antennas only
  ~37% use/produce Panel/Phased Array antennas
  ~25% use/produce both reflector and Panel/Phased Array antennas

- Frequency:

  ~No entrants are operating in Ka-band only
  ~62% are operating in Ku-band only
  ~38% are operating in Ka-/Ku-bands

2. BUC and tracking performance (Aeronautical)

The Effective Isotropic Radiated Power (e.i.r.p) depends on the gain of the antenna and on how powerful the BUC is. The EIRP values range from 44dBW to 57dBW. The values are relatively lower than in the maritime environment since the nature of the aeronautical platforms implies having flat and lightweight antennas.

Some entrants specify the maximum rates that their tracking unit can follow. The rates are ranging between 12°/s to 24°/s which are lower than in the land mobile and maritime environments. The motion dynamics in the aeronautical domain are generally lower especially for the civil sector.

3. Services (Aeronautical)

The same categories of services in the land mobile and the maritime market segments can be seen in the aeronautical area. The services provided can be divided to:

1. System related: sub-system manufacturing, system integration or satellite system operation

2. Application related: broadband communication, IP bridging, military surveillance, emergency responding, etc.

4. Conformity with standards (Aeronautical)

Same as in the land mobile and the maritime environments, It is either stated that the product is in conformance with some standard (recommendation/Norm), or that it has a successful trial in one or more of the type approvals, or in few cases it is explicitly stating the maximum pointing error of the antenna.

In the following, we summarize the main points (concerning off-axis emissions and tracking performance) in the aeronautical related standards and type approvals.

Recommendations and Norms (Aeronautical)

- **ETSI EN 302 186 (Aircraft Earth Stations AESs at Ku)**
    - An e.i.r.p. mask similar to the one in the **ETSI EN 302 977 Norm (VMES at Ku)** is stated only for the co-polar pattern. The compliance to this mask has to be tested.
    - The radiation patterns (E-/H- planes) as well as the antenna maximum gain have to be measured.
    - The maximum pointing error of the antenna is declared by the applicant. The commitment to this limit has to be tested.
    - How the tests are performed or in which Testing Entity is left open for the applicant.

- **FCC 25.222 (Earth Stations on Vessels ESV at Ku)**
    - The e.i.r.p. mask is stricter (Narrower) than the ones defined by ETSI. The compliance to this mask has to be tested.

    - The conditions are very much the same as in FCC 25.226 for VMES.
    - A maximum pointing error of 0.2° is to be maintained.
    - The maximum pointing error of 0.2° can be exceeded as long as the e.i.r.p. limits are preserved. The new maximum pointing error has to be declared by the applicant.

  - The VMES has to demonstrate the ability to cease transmission if the pointing error exceeds 0.5° for 100 milliseconds.
  - The VMES has to have the ability to detect any excess pointing error and has to demonstrate the ability to cease transmission within 100 milliseconds.

- **ETSI EN 303 978 (ES on Mobile Platforms at Ka)**
  - Mobile platforms are defined as trains, vessels, aircraft or any non-stationary vehicles.
  - The e.i.r.p. mask for the Ka-band is narrower than the one **ETSI EN 302 340 (ESV at Ku)**. The compliance to this mask has to be tested.
  - The radiation patterns (E-/H- planes) as well as the antenna maximum gain have to be measured.
  - The maximum pointing error of the antenna is declared by the applicant. The commitment to this limit has to be tested.
  - How the tests are performed or in which Testing Entity is left open for the applicant.

- **FCC 25.138 (Blanket Licensing provisions at Ka)**
  - The e.i.r.p. mask is generally wider than the ones defined at Ku.
  - No pointing accuracy requirements stated.

On the other and, the Type approvals are operator dependent and the underlying procedures are similar for the different environments.

Statistical Analysis (Aeronautical)

From the entrants list, the following statistics can be derived:

- ~38% do not state anything about certifications
- ~25% state that they comply with ETSI/FCC norms but without any details under which motion conditions they tested it
- ~ 38% of the manufacturers perform type approvals
  - by Eutelsat /Intelsat/Inmarsat/Hispasat
  - nothing mentioned about motion profiles – only turning tables mentioned!!)
- ~13% define the motion track which they used e.g. churchvilleB (not for all products)
- ~38% specify the tracking accuracy of their SOTM terminals
  - Only 13% specify under which conditions or at what limits (e.g. churchvilleB, 99% of the cases, up to 70°elevation..)

***General Notes* (Aeronautical)**

- The lack of a standard type approval leads to:
  - non standardized products as shown in the Statistical Analysis (38% do not specify anything about certifications)
  - Cost/time inefficiencies due to running many similar Type Approvals for the same product line.
- Standard reproducible motion profiles are overall not specified
  - Non-standard but frequently used motion tracks e.g. ChurchvilleB and Millbrook PG.

It can be again seen how analyzing the SOTM value chain helps showing the need for a standardized testing methodology or Type Approval.

5.1.4 Analysis of Modems

Modems were researched separately since not all system integrators and VARs specify the type of modem which is integrated in their SOTM terminals. Many antenna manufacturers state that their antennas are modem transparent, in other words, any modem with the SOTM functionality can be used behind the antenna.

Table 7 lists most of the modems which are used in the satellite communications market.

Analysis:

- Almost all modems operate in L-band.
- The data rates range between 1 Mbps and 8 Mbps
- Viterbi, Turbo Product Codes and LDPC are mostly used for Forward Error Correction.

company	Product(s)	Tech. Specs.					
		Data Rate	Symbol Rate	Frequency	FEC	Modulation	Output Power
Comtec	CDM-625A	18 kbps to 25 Mbps	18 ksps to 12.5 Msps	50 – 180 MHz	None/viterbi/RS/LDPC/TPC	PSK and QAM	0 to -25 dBm
	CDM-760		DVB-S2: 100 Ksps to 150 Msps	950 to 2150 MHz	None/viterbi/RS/LDPC/TPC	QPSK, 8PSK, 16APSK, 32APSK	0 to -40 dBm
iDirect	Evolution X3					PSK	7 to -35dBm
	Evolution X5	up to 150 Mbps	up to 45 Msps	950-1700 MHz	LDPC/TPC		
Paradise	Evolution PD10L L-Band	4.8kbps to 10 Mbps	5Msymbol/s capable	950 - 1950MHz	TPC/viterbi/sequential/LDPC/RS	PSK and QAM	
	PD60L DVB S2 L-Band	4.8kbps to 20 Mbps		950-1950 MHz	TPC/viterbi/sequential/LDPC/RS	QPSK, 8PSK, 16APSK,QAM	
Anacom	2002L	128 kbps to 5 Mbps		950-1700 MHz	vitebi/RS	QPSK or none	0 to –25 dBm
Memotec	NetPerformer	up to 8 Mbps					
Newtec	MDM6000	155 Mbit/s		950 - 2150 MHz	BCH/ LDPC	PSK	7 to -35dBm
Viasat	Linkway			950–2150 MHz	TDMA/MF-TDMA	PSK	
Radyne	DMD20 LBST	up to 8 Mbps		950 to 2050 MHz	vitebi/TPC	PSK/QAM	0 to -25 dBm
Datum	M7LT	up to 60 Mbps	2400 sps to 14.76 Msps	950 to 2150 MHz	None/viterbi/RS/LDPC/TPC/TCM	PSK/QAM	
Romantis	UHP-1000	up to 8 Mbps		950 to 1550 MHz	BCH/ LDPC/viterbi+RS	SCPC and TDMA using PSK	-5 to -30 dBm

Table 7: Modems listing

5.2 Cost inefficiencies and problems

5.2.1 Issues common to the land mobile, maritime and aeronautical SOTM environments

The market dynamics are having a significant impact on the buying processes influencing the satellite operators and manufacturers. In a number of instances the criteria being imposed to improve the QOS for the satellite operator is seen as a barrier to business for the actors involved in the manufacturing and value added reseller (VAR) segments for the market. As an example the market has seen instances where legacy specifications that have little impact on the QOS for the satellite operator have adversely impacted the cost and time to market for the manufacturing segment. The following two sections describe the SOTM market dynamics, first from the satellite service provider perspective and second from the manufacturer VAR perspective. A key objective for this study will be to determine the proper balance between what sometimes appear to be conflicting interests.

Market Dynamics and Influences from the Satellite Operator Perspective:

- SOTM recognized by operators' sales department as one of strongest emerging sources of short, medium and long-term revenue.
- Key verticals include military, maritime, aeronautical, trains, vehicles.
- While SOTM volumes are small relative to fixed solutions, service-related revenue is disproportionately higher.
- Operators are being approached by increasing numbers of new SOTM manufacturers whose customers -- the VARs -- want to use their systems on the operators' platforms.
- New entrants often try to secure market share by selling at the lowest price.

- There is strong pressure from the commercial side of the satellite operators' companies -- and from their customers, the VARs -- to encourage the use of the lowest-cost systems.

- Cases of severe interference caused by these systems are mounting.

- This comes back to the operators in the form of financial losses associated with degraded quality of service, dissatisfied customers, major expenditures associated with identifying and stopping interfering sources and, in some cases, penalty payments.

- Operators are overwhelmed with the volume of requests for various SOTM terminals, which is compounded by the lack of a standardised testing and type approval mechanism.

- Competing operators from Europe, Asia, and the Americas are now working together within the GVF MRA Satellite Operator Sub-Group where they are developing minimum standard specifications for classes of earth station equipment.

Market Dynamics and Influences from the Manufacturer / VAR Perspective:

The nature of perspectives on market dynamics and influences here depends partly, if not largely, on the structure of the company/companies undertaking the supply of antennas, and modems, and undertaking the integration. For example, companies like Hughes or ViaSat (which have historically dominated supply in the market for fixed VSAT terminals), which have already become predominant in the supply of equipment and service into the aeronautical SOTM market, are highly vertically integrated all the way up and down the value and service chain (owning the satellite, owning the Hub, manufacturing the equipment).

Other companies in the general manufacturing and VAR space are not vertically integrated in this way, such companies more typically being located in the maritime (e.g. SeaTel, KVH) and land (e.g. GD SATCOM) SOTM markets. In the maritime and land SOTM space companies operate in a different and more segmented, as opposed to integrated, way. This environment features more actors, more commercial transaction interfaces between the different elements of the SOTM solutions chain.

Under this heading, the grouping together of Manufacturer and VAR is intended to reflect the fact that the market situation is a complex mix, with some companies being only manufacturers, others being part manufacturer and part VAR, and others being wholly VAR. This environment is to some extend reflected by the graphic ‘The Value Chain Components’, shown as Figure 3 which attempts to capture the interaction between each of the “actors” in the SOTM value chain. There are at least three paths for an end user to implement their required satellite solutions. They can either (i) purchase service and perhaps product from the satellite operator; (ii) contract with a VAR; or, (iii) purchase approved equipment from a qualified integrator or manufacturer and set up their own service. The choice of path will depend on the end user’s level of expertise.

- The Rx/Tx earth station manufacturing business has evolved dramatically during the past 20 years: In 1998, there were approx. 60,000 fixed installation VSAT antennas sold globally per year; today, the same number are sold in a three-month period by one company in one country.
- As with any mass-market business, margins are razor thin.
- This has driven consolidation of those already in the Rx/Tx manufacturing sector and it has attracted new manufacturers interested to take advantage of a new growth area.
- Some well-established manufacturers of Rx/Tx satellite earth station equipment have added SOTM products, as there is strong growth in demand and as -- due to its complexity and need for high performance -- it is a higher-margin product.
- New entrants, however, are "buying" market share by selling primarily on lowest price.

- Some VARs are rewarding this strategy by placing orders for the cheapest equipment in what is rapidly becoming a very competitive market.

- This creates tension with the satellite operators who, while their commercial departments want to sell more bandwidth for SOTM customers, their operations groups are complaining bitterly of escalating rates of interference arising from poor-performing SOTM systems.

- This also creates tension for suppliers of premium-grade SOTM equipment who are losing business to manufacturers whose products do not perform well and who are under pressure to compete with lower prices and slimmer margins.

- As competition in the SOTM manufacturing business intensifies, there is increasing recognition that having a globally-recognized, cost-effective industry standard type-approval program would be good for all manufacturers.

- Well-established manufacturers are being joined by new entrants in the GVF MRA Working Group, where there is strong support for the work being conducted by the Satellite Operator Sub-Group.

The Buying Process:

When considering the various transactions within segments of the overall value chain, for example, Manufacturer to Integrator, and Integrator to Service Provider, it is essential to take account of the comments above which describe and reference the different dynamics which result from the relative levels of company vertical integration – high in the market-dominant provider companies in the aeronautical environment, and lower in the various companies contributing to solutions within the much more segmented maritime and land environments.

This study calls for four elements in analysing the "Buying Process". These are summarised as:

1. **Waste & Inefficiencies in business transactions related to the SOTM market sector.**

   There are a number of inhibiting factors which prevent driving the SOTM business to the highest possible level. Each individual factor can be problematic, but they are often manifest in combination creating multiple inefficiencies. Study responses to date indicate that the challenges are many and include smaller antennas and higher bandwidths, pointing accuracy increases as well as the potential for causing interference if products fail to meet specification requirements. Regulatory constraints are the primary inhibitor which in turn, flows down to the product quality requirements. There has been a massive shift in the market over the past five years for integrators/vendors to demand mandatory compliance to SSO specifications.

   The SSO specifications are not discussed in detail in this document. Each of the satellite operators have their own detailed specification variants, which, of course, have to comply with ITU requirements, and do feature some common detail, but are essentially still different. The Satellite Operator Sub-Group is currently working to address a common set of specifications that are directly relevant to the SOTM environment and will comprise a contribution to this study when in the public domain (currently under NDA, but expected to be public shortly), leading to an output from this study in the form of recommendations for a harmonized set of SSO specifications.

   This massive shift has resulted in product requirements that are the limits of what available technology can supply. GX requirements have been cited as a very good example in trying to achieve compliance with speciation requirements such as the FCC 25.209 with a 60 cm sized antenna aperture. This has driven designs to use larger apertures as well as seeking waivers from regulatory specifications. For larger size SOTM antennas the pointing accuracy has to increase as a result of decreasing antenna beamwidths. Thus, pointing large aperture Ku-band antennas (and more so with large Ka-band antennas) becomes much more of a challenge for the technology.

Some inefficiency regarding business transactions resulted from a lack of understanding on the part of the end user customer for the "cost of ownership". There is no common industry practice for specifying products in promotional materials and key parameters are often left undefined or poorly defined. Many manufacturer specification sheets to not address, for example, EIRP spectral density on axis required for a terminal to maintain a compliant level of interference. (NB. Under the terms of the confidentiality agreements entered into for the conduct of the study survey questionnaires it is not possible to identify this respondent by name or segment.)

As well as the factor of EIRP spectral density, poor tracking performance has been cited as impacting link availability, resulting in issues relating to quality of service warranties. These issues boil down to defining how products are specified and how terminal performance is qualified through type approval testing. Eutelsat has developed good qualification test procedures but that there is room for improvement for SOTM terminals with regard to terminal tracking performance. Invoking GVF-105 and better definition for standard motion profiles is seen as a move in the right direction to address these issues. Additionally it has been recognized that vibration profiles should be defined as part of the approval process. [See 5a below]

These issues need to be tackled working with manufacturers' partners, those who purchase the antenna systems and then integrate them in to their network systems. An example may be where a sales brochure lists a performance parameter which then may be compared to competitive claims that have been exaggerated to influence the buying process. <u>Using antenna gain as an example, there is no uniformity in how antenna gains are presented to the market</u>. Variables include defining the gain at the antenna feed or BUC interface. Likewise some manufacturers describe their antenna performance in terms of "typical gain" and neglect to mention that there may be points within the advertised band where the gain may fall significantly over a narrow band. [See 5c below]

Regarding Type Approvals requirements, one problem results from the lack of consistency in specifications. The FCC & ETSI call for different EIRP spectral density specifications for off-axis compliance. GX has taken a pragmatic approach to this environment since it operates as a global network. It requires that its specifications comply with all of the regulatory specifications. [See 5b and 5d below]

When competitive systems fall short of end user customer performance expectations it is important from a business perspective to understand if this adversely impacts purchasing decisions regarding follow-on procurements.

Indications are that it is common for manufacturers' partners to conduct additional testing using the integrator's facilities before the antennas are deployed. This to confirm compliance to advertised specification performance. Small integrators [without adequate test facilities] will often deploy products from manufacturers based on advertised performance and will not conduct additional performance validation tests.

A noted concern was that regulatory specifications often do not have an "operational" impact on the satellite link. In the case of Inmarsat, some specification callouts appear to have been non-applicable holdouts from prior requirements. This requirement falls in to a "check-the-box" category for the license application rather than impacting a true "operational" concern. One example addressed the exceeding of a sidelobe mask at 70 degrees off-axis by 2 dB. The development of a new product was used to further substantiate the value of addressing non-operational specification call-outs. [See 2a and 2b, and also 3a and 3b, below]

Smaller integrators and equipment vendors/dealers tend not have the resources to validate product performance, and such sales to these smaller integrators/vendors which lack the capability to validate a manufacturer's product performance (e.g., a local dealer who installs maritime terminals on a large yacht) can be problematical. The market division between the major and smaller companies is approximately a 60/40 to 70/30 split.

As well as typically not have the engineering staff to evaluate the site or location for optimally locating or placing the terminal, these smaller-scale operations have a propensity to purchase SOTM terminals on price alone as they do not have the capability to validate the manufacturer's true product performance. This results in follow-up service calls requiring visits to the vessel on which the equipment is installed to diagnose the problem source. Misdiagnoses often result with the antenna being targeted as the problem source rather than its location on the vessel. One representative has employed a "train-the-trainer" program and training for their top ten dealers to eliminate problems resulting from inappropriate SOTM positioning and operation, indicating the value of having installer and operator training for maritime terminals.

Examining the idea that specifications sheets, or several specifications sheets, could serve as a useful reference point to standardize requirements for SOTM terminal specifications – providing the justification for the performance requirements identified in the specification sheets as helping to steer "best business practices" – one recommendation was to take a Eutelsat type approval certificate as a template, expanding it to include the factors [pointing and tracking accuracy criteria] required for maintaining link integrity, thus benefiting the end customer operations.

2. The cost impact and how it affects the vertical components of the value chain (Satellite System Operators, Manufacturers, Value Added Resellers [VAR's] and End Users.

[a] In this example, the engineering design was completed in approximately ten months, but it took an additional 28 months to

achieve full compliance with non-consequential specifications at a substantial cost. Non-consequential specifications may be understood as those specifications which are cited as a requirement by a satellite operator to cover scenarios where other actors in the value chain may have their own applicable specification requirements. Thus, a satellite operator will have its own set of core specifications, but may include further specifications which it understands may be the additional requirements of a regulatory body such as the FCC, or Anatel, etc. (NB. Anatel is the independent National Telecommunications Agency of Brazil with powers to grant, regulate and supervise telecommunications services. See the graphic ‘The Value Chain Components’, shown as Figure 3 which captures the interaction between such regulatory authorities as “actors” in the SOTM value chain.)

[b] The FCC and Anatel appear to be the leaders in terms of requiring non-operational regulatory specifications. These specifications have delayed product introductions and resulted in significantly higher costs that are passed on to the end user. The challenge with Anatel is one of inconsistency. Anatel specifications have changed three times over the past six years. Anatel resolution 572 covers qualifying the antenna optics and is concerned with the antenna gain mask whereas resolution covers qualification at the system level [EIRP spectral density].

3. Quantification of the cost drivers caused by the current inefficiencies.

[a] In this example, the cost was > €2.0 million. The more complex design, that was required to satisfy “non-operational” specifications, resulted in a recurring price increase of > 15%. Thus, the problem causing such price increases in this instance is the imposition of specifications which have no bearing on the quality of the satellite

link or have no bearing on the prevention of interference to other services. The initial problem of the costs in meeting the additional specifications is further exacerbated by yet more additional costs associated with delays in bringing a product to market.

[b] Antenna type approvals through Anatel typically require one year to complete at a cost of approximately € 50,000 for each variant of a particular antenna.

4. Ranking the cost drivers to determine where to concentrate study focus to optimise the SOTM market environment.

Separate and individual ranking of the various cost drivers is complex because of the inter-relationships between, and inter-connectedness of, the various factors. Further study responses may provide the necessary additional data and perspectives to unravel this inter-connectedness. It is nevertheless clear that the cost drivers do include: regulatory issues, type approvals issues, customer product understanding, and clarity of performance requirement identification.

5. Identification of Improvements to Optimise the Buying Process.

[a] Analysis of data obtained by GVF in the course of conducting interviews for the study survey questionnaire so far has highlighted suggestions that the satellite industry should develop "gold standards" to identify EIRP spectral density limits and relate these limits to the gain for terminal antennas. The specifications should be integrated with the SOTM performance to published motion profile environments.

[b] GVF itself has been encouraged by a leading SOTM antenna manufacturer (interviewed for the study survey questionnaire under the terms of a confidentiality agreement) to take the lead in defining one EIRP density specification that would satisfy the requirements of the major regulatory bodies. This would provide industry with

"one number" for EIRP spectral density to compare different antenna systems. There is evidence that GX would be supportive of this position, given that GX has asked the GVF to all or most of their type approval testing beginning in the foreseeable future, as well as providing input to the GVF in support of the ESA SOTM study.

[c] Survey recommendations point to the manufacturer to defining the minimum gain within a given band and further identify the interface where to which the advertised gain is referenced.

[d] Provision of clear definitions as to how gain and other critical parameters are defined is essential when type approval certificates are issued. Common definitions for all type approvals should be used when certifying products.

[e] The accumulation of data through interviews for the study survey questionnaire is a continuing process. To date, study survey data points up that an important factor contributing to the optimisation of the buying process is antenna gain related. Further study survey questionnaires, based upon a growing breadth of actors in the SOTM environment, are very likely to reveal other transaction-related problems affecting the buying process in due course. One such example has already been provided here, in connection with licensing issues, as referenced immediately above, in part 4.

5.2.2 Sector-based variation in the dynamics of Current Buying Process influences

Section 5.2.1 addresses those issues that are broadly common to the SOTM market sectors aeronautical, maritime, and land. The following additional sections, wherein distinctions and variations between the three markets, variously influencing the buying process in each case are cited, should be read in conjunction with this overall section. Analysis and observations presented here in part derive from various GVF-run conference events covering the aeronautical and maritime (shipping and offshore oil and gas) environments.

Aeronautical SOTM:

The aeronautical SOTM market is a relatively new and emerging one, and one that still tends to direct prime focus to the provision of a richer and more interactive infotainment experience for passengers as a competitive business offering that is just as, if not more, important than competitive ticket pricing, scheduling, and routing. This is itself a major influence on buying process decisions for many types of airlines (flagship, and traditional airlines, plus some regional, and low cost carriers) where passenger take-up rates are showing signs of growth but are not yet high enough for airlines to break even.

A Euroconsult report highlights that flagship and traditional airlines long-haul wide-body aircraft account for about 75% of VSAT-installed vehicles where the business and buying driver for the airline operator is improving the existing passenger experience, whereas for regional and low cost carriers with narrow-body aircraft over short-haul routes the driver is to offer a connected experience where no in-flight-entertainment (IFE) is currently provided.

Some 1,300 commercial aircraft across 59 airlines worldwide offer in-flight connectivity at the passenger experience level – which typically includes a three-facet package of Internet, and Mobile, and live Entertainment (on larger aircraft recorded Entertainment is usually provided by on-board equipment rather than using satellite-based connectivity) – for which the Euroconsult report shows a passenger take-up rate of 7%, an average revenue per user (ARPU) of US$11 per session, breaking down into US$12 for Internet service, US$3.50 for Mobile connectivity, and US$5 for live TV.

In a research report produced by one of the respondents which is now planning to contribute directly to the study survey questionnaire it was shown that two-thirds of connected air travellers are seated in economy class. This factor further prompts airline carriers to focus on minimizing the costs to the passenger of using Internet, Mobile, and Entertainment connectivity. However, in addition, the same research showed that 55% of business class travellers are reimbursed for their in-flight-connectivity (IFC) by their employer, and this usage is less pricing sensitive.

The same research showed that despite relatively limited passenger take-up rates revealed in other reports (see above) almost 90% of international passengers have an interest in in-flight Internet. This is a major influence on airline buying process decisions because IFC is increasingly driving passenger airline preferences, with 25% of travellers changing from their originally preferred airline to another carrier which offers Internet equipped flights.

Airlines want:

(a) Their passenger customers to have a deeper, richer engagement with their brand
(b) Customer loyalty
(c) Informed marketing strategies across traveller segments

These can now be best developed by the availability of IFC and the fact that IFC is assuming a more prominent position across overall branding and marketing activities means that the buying process is tending towards accelerated development of IFC offerings as a matter of business development priority.

Additionally driving the aeronautical SOTM buying decision-making process, beyond serving only the passenger experience is capability to serve cockpit requirements, flight operations requirements, and crew-passenger real-time information exchange.

Maritime SOTM:

The maritime SOTM market has strong historical foundations in a long-standing imperative for mobile communications which has until recently only been addressed by MSS terminals and services. MSS still stands for the bulk of maritime installations, but SOTM VSAT terminals are now in increasing demand across a market which includes some 121,000 addressable vessels which in a (Euroconsult) report of 2013 were served by 352,000 MSS terminals and 12,000 VSAT terminals. In the same report, the equivalent forecast figures for 2023 are approximately 570,000 MSS terminals and approximately 42,000 VSAT terminals.

As noted above, this maritime market is served by a highly segmented Manufacturer to Integrator to Service Provider value chain which includes 70+ VSAT service providers alone. This situation is likely to see further merger and acquisition activity which will result in fewer actors within the value chain of this sector, therefore reducing segmentation and rendering the buying process in the sector more simplified. At the same time SOTM VSAT will facilitate significant increases in broadband penetration into the maritime sector – forecast by Euroconsult to reach a compound annual growth rate (CAGR) of 28% by 2022 – to meet demand prompted, amongst other factors, by deceases in satellite capacity costs.

Other key growth prompting factors reflect structural shifts in the nature of broadband demand in the maritime sector, demand which is sub-divisible according to the segment in question, i.e., Merchant Ships, Passenger Ships, Offshore Support Vessels and Rigs, but which overall may be encapsulated as demand for broadband access for: ships' crew welfare and training requirements; managing the "office at sea"; real-time weather report-based route planning; in the longer term control of autonomous/unmanned vessels; cruise passenger broadband connectivity; large-scale data file transfers; videoconferencing; video-based supervisory control. All of these applications in the maritime environment are in high-growth and the capacity to serve them is an important driver to the buying process, particularly as many of these applications centre on the Cloud computing environment which supports the streaming of terabytes of data between ship and shore where data is key to successful business operations as in offshore oil and gas.

On a somewhat different note, one respondent to the study survey questionnaire who is a maritime sector end user in the oil and gas segment was forthright in his focus on one element in optimising the SOTM environment, and making the reason to buy VSAT-based solutions all the more compelling – the resolution of licensing issues. Operations in the domestic territorial waters of different nations necessitates adherence to a wide range of licensing processes, some of which can take up to five months to execute. This is much longer than the period of notice received by the respondent company as to when its services are required in such territorial waters, causing concern that they cannot be properly licensed in time for their operations. This incurs problems ranging from fines to equipment confiscation (or even jail sentences in extreme instances). On arrival in a given country's territorial waters, the company's rig is inspected by customs and the respondent company has to declare all of the equipment that will be used.

Overall, in the maritime sector the buying process will be accelerated as the market gets more of what it wants from the satellite industry, namely: greater bandwidth with greater speed and unlimited traffic volumes, combined with lower and fixed costs.

Land mobile SOTM:

The land SOTM environment is the most divergent in its constituent parts, including, in the commercial environment, fleets of road vehicles (e.g. freight trucks, passenger coaches), and passenger trains, and in the military environment, fighting and support vehicles.

In the purely commercial environment the business buying process incorporates not only the fact that, as noted above, land SOTM providers operate in a different and more segmented, as opposed to an integrated, way (cf. the aeronautical sector), but there are more options available to the buying process. The aeronautical and maritime sectors are, by definition of the specific nature on their mobility environments, users of satellite-based services only, whereas the land sector is not, and may avail itself of the technology and service offered by the terrestrial mobile industry.

Terrestrial mobile broadband technology and services are competitive with SOTM in this sector at least in as far as terrestrial deployments are available in more urbanized areas and along inter-urban main road and rail corridors. This factor brings an elevated level of alternative supply-chain competitiveness to this sector.

6. Transaction Needs

After the analysis of the SOTM value chain and the assessment of the current buying process identifying the main sources of wastes and inefficiencies, it was important to approach the market contributors for consultation about their needs and how they see the potential to overcome the inefficiencies by introducing SOTM standards.

Task 3 of this study was formulated to achieve this goal in a three-phase process:

1. Preparation of the consultation plan (WP 3100).
2. Implementation of the consultation plan followed by analysis of the results (WP 3200).
3. Initial recommendation of a standard (WP 3300).

The objective (WP 3300) for developing recommendations for new SOTM standards was modified, with ESA concurrence, following input received from members of the satellite operator community. This was presented during the Milestone 1 meeting at ESA facilities. **The modified objective is to recommend and promote best practices for test procedures to validate the performance of SOTM terminals and gain industry acceptance of these procedures for equipment type approvals.**

The challenge has been that the satellite operator community could not reach consensus regarding standards and specifications for the SOTM market. A satellite operator sub-group, operating under the GVF umbrella beginning in 2013, has been working to define minimum performance requirements for newly introduced equipment that each of the individual operators would recognize as acceptable for accessing their services. The sub-group document establishes the performance boundaries between minimal acceptable performance and unacceptable terminal performance. Its primary purpose is to secure an interference free environment for satellite operations when new equipment is deployed in to the market. An individual satellite operator may still define more restrictive performance standards for accessing their services.

This has been a difficult task for the industry and the sub-group has worked diligently to develop these standards which the GVF together, with

the satellite operator sub group, could disseminate to industry. Documents have been produced but because of the sensitivity and different interests of each operator, the information is restricted by a Non-disclosure Agreement NDA. The GVF has recently been included in the NDA agreement and is impressed by the progress that the sub group has achieved. We cannot go in to details regarding the specific minimum performance standards that the sub group has developed. Without violating the restrictions of the NDA, we can say that the approach taken is to categorize earth stations in to broad groupings and tailor the minimum acceptable performance to the requirements of each group. Categories were divided between the following: fixed higher power earth stations, traditional fixed VSAT applications, products for the SNG market, mobile applications including land mobile and maritime environments. The recommendations also recognized the different performance levels from various aperture sizes.
With regard to this study, the GVF / Fraunhofer IIS recommendations for SOTM terminals will be reviewed with the satellite operator sub-group to ensure that the provisions of the NDA are not violated.

The GVF has followed the key activities enumerated in the ESA Statement of Work (SOW) Work Logic Plan and has progressed through Tasks 1 and 2. As a key component of this activity the GVF and FHG identified 92 companies that provide SOTM products and services to the SOTM market. Each of these companies was evaluated for their relevance to the market and a questionnaire was developed to determine what these actors saw as barriers to their business and time for introducing new products to the market. Additionally the survey questionnaire covered the participant's perspective of how the market was developing, its future growth potential, product specifications and regulatory requirements, as well as the impact of sub-standard equipment on the market. The survey covered activity in the maritime, land based, and airborne market sectors and addressed the concerns of the participants. These included equipment manufacturers, integrators and satellite service providers. Each of the manufacturing / integrator participants provided feedback regarding the influence of regulatory specifications on their business. It was ultimately recognized that the satellite service providers represent the final authority for what is required to access the services they provide.

The activates undertaken for the Value Chain Consolidation (Task 1) and establishing the Current Buying Processes (Task 2) lead to the presentation for the completion of the first contract milestone (Milestone 1). Satellite operator participants at the ESA Milestone 1 review included Eutelsat, Hispasat Inmarsat, O3b and SES. It became evident during the ESA meeting that arriving at a common set of standards that satisfy all of the satellite operators would be a challenge. As a result ESA suggested that the study will be refocused on achieving consensus on developing a common set qualification test procedures which would be acceptable to all of the operators. These would be embodied in GVF-105 and include the motion profiles developed by Fraunhofer IIS as a part of the study. Individual satellite operators would review the test results gained by following GVF-105 procedures and reach a determination as to the acceptability of a particular product for accessing their services. In order to accomplish this objective, GVF-105 (with the Fraunhofer motion profiles) has been distributed to a wide cross section of GVF members that represent various sectors of the SOTM market and a corresponding consensus was achieved.

6.1 The consultation plan

The GVF / Fraunhofer survey was conducted to identify the factors which the various companies participating in the market determined had the greatest influence on their business. The questions developed for the survey are summarized in the following eight points. As discussions with the SOTM market participants' progressed, additional subject matter was introduced. The detailed survey results are summarized in Section 6.2 and include the expanded comments

1. Market Overview: SOTM production & sales seen as a significant growth opportunity in terms of market demand and if so at what level & what directions? What approximate percentage of sales does the participant expect SOTM to be now? Which of the verticals is going to play out fast and first. Is maritime or land SOTM driving the business now?

2. Why is land SOTM less of a growth market now?

3. What are the inhibiting factors or areas where improvement in any regard affecting any layer of the value chain can drive the business to the highest possible levels for the participant? There is a type approval agenda here but this is a broader question that includes regulatory issues, type approval, customs, technology inhibitors etc. What are the challenges and what is "keeping you awake at night"?

4. Who at a customer that has their "hands on the spec sheet"? Is it a ship owner manager? Is it a value added reseller [VAR] that purchases and packages a system for a prescribed bandwidth and selling it to a ship owner?

5. In terms of what the participant is encountering regarding type approvals requirements (Gx, Intelsat, Eutelsat, AsiaSat etc.), what closest approximation should be considered to serve as a baseline for type approval testing? How do these requirements relate to the specifications imposed by regulatory agencies such as the FCC and ETSI etc.?
6. When competitive systems are sold in to the market place and fell short of customer performance expectations, have they adversely impacted customers and reversed decisions regarding follow-on procurements?

7. This is a follow up to the prior question regarding smaller [mom & pop companies] that do not have the resources to validate product performance. Who are the smaller companies and what percentage of the market is served by these companies? What performance problems have resulted from products sold by smaller [mom & pop] companies who lack the capability to validate a manufacturer's product performance? How valuable is it to have installer and operator training for maritime terminals?

8. Does the participant have an example of a spec sheet, or several specifications sheets, to serve as a useful reference

point as the study looks to standardize requirements for SOTM terminal specifications? It would be helpful to provide the justification for the performance requirements identified in the specification sheets to steer "best business practices".

What is the value of recertification programs? This is an Anatel concern where recertification tests are required for systems that have not undergone design or manufacturing changes in perhaps 20 years?

- Is the ESA study pushing to one standardization / certification methodology for companies that participate in GVF type approvals? Does this involve employing qualified test labs and utilizing recognized test procedures?
- Is there a set fee structure for conducting tests and are the GVF encouraging independent test labs to participate in type approval programs?
- Is the GVF involved with the RTT&E directives? Anatel has typically combined the requirement for RTT&E compliance with the need for conducting radiation pattern measurements.

6.2 Consultation implementation and market feedback

Representatives from different sectors of the SOTM market were contacted and the questions outlined in Section 6.1 were used as a guideline for discussions to determine their perception of market status and their evaluation of the most significant factors that impacted their business.

The responses were grouped by vertical market sectors. These included the maritime mobile market, land-based mobile market, airborne market. Off-shore oil exploration was included as a separate subgroup to the maritime market. Although considered as stationary installations, off-shore oil rigs require that satellite terminals employ dynamic tracking to compensate for the natural movement of the oil rig resulting from climatic effects and rig operations. While the majority of SOTM terminals deployed to date utilize traditional tracking reflector antenna solutions, new technologies are poised to enter the market that employ electronically scanned phased arrays. The phased array (and similar solutions) does not require any physical antenna motion to maintain the satellite link. We decided to include manufacturers producing this equipment in an “Advanced Concepts” vertical grouping. The new technology provides some benefits in some areas (light weight, low profile and tracking speed) which favour solutions for airborne SOTM communications, however these solutions also come with a number of negative factors (antenna patterns and gain change as a function scan angle which in turn degrades the link margin at maximum scan angles. Adjacent Satellite Interference ASI represents another area of concern with the development of coma lobes as the array pattern is scanned off-axis). The final grouping comprised the satellite operators and included AsiaSat, Eutelsat, Inmarsat, Intelsat and SES. Each of these operators require similar (but different) specifications regarding the performance of SOTM terminals accessing their services. Essentially the differences between the individual satellite operator specifications would remain in force but compliance with these standards would be demonstrated by following industry recognized and accepted test procedures (such as those introduced in the updated GVF-105).

The results of the market survey by vertical sector are summarized in the six following tables (Tables 8 through 13).

The implemented survey individual sheets were submitted as part of Technical Note 3 (TN3) of this study.

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QUESTION TOPIC		MARITIME MARKET SECTOR
1	**Production & Sales Growth**	• Market seen as offering stronger growth over land based systems. • Market expended to experience stronger growth when LEO systems are deployed to serve multiple users • Activity increasing in Ka-band.
2	**Growth by Market Sector. Why is land-based SOTM declining?**	• Land based market facing stronger competition from terrestrial • Military spending has declined. • SOTM market expected to expand when LEO constellations are deployed. • Further expansion predicted when market sorts itself out between the Intelsat Gx and EPIC satellite services.
3	**Inhibiting factors influencing SOTM market & sales growth**	• Regulatory constraints seen as primary inhibitor as SOTM terminals decrease in size giving rise to potential ASI issues. • Smaller SOTM terminals have increased the requirement for waivers. • Larger terminals have increased the tracking accuracy requirements. • Poor consistency in specifying products has increased confusion to customers purchasing services.
4	**Which entities are driving the product specifications?**	• Seen as more of an issue with the manufacturer's partners who integrate the overall system design. The challenge is in specification uniformity and how products are specified.
5	**What are the dynamics influencing product type approval and relationship to regulatory standards?**	• Type approvals are seen as a worthy goal but the satellite operator community to this point has not reached agreement on specification requirements. Significant differences are seen between FCC, ETSI and the individual requirements of the satellite operators. • Equipment suppliers to the maritime market are calling for common definitions for SOTM equipment. Examples cited included antenna gain (where referenced?), antenna performance across a band to reveal where there may be localized drops in performance.
6	**What are the consequences when sub-standard equipment permitted in market**	• It is common for a manufacturer's partner to validate terminal performance for compliance with advertised product specifications. • Smaller sized manufacturers tend not have the test support infrastructure and this has resulted in ASI problems for the satellite operators. • Regulatory specifications often do not have an operational impact on the satellite link. Inappropriate (check the box) specifications have delayed product introductions and significantly increased product price.
7	**Product Integrity (large & small scale manufacturers)**	• An example of a "smaller" company might be local dealer who install terminals on a large yacht. Typically these companies do not have the expertise to evaluate and assess optimum locations for equipment placement. Expertise often lacking regarding external influences such as blockage and vibration. • Market split between large and small companies is approx. 70 / 30, • Smaller companies tend to procure equipment on price rather than analyzing the requirements to provide optimum solutions. This has resulted in after sales service calls to rectify short comings in link performance. • Training for proper equipment installation and placement is seen as serious short coming with smaller companies.
8	**Responses to sample product & system specification requests**	➢ One maritime market participant recommended expanding the approach followed by Eutelsat to include firm specifications and test procedures that addressed all of the factors impacting the integrity of the communications link. ➢ Manufacturers in this market segment tended to treat their performance specifications as proprietary – not wishing to benefit competitors.

Table 8: Top level responses from Maritime Market Sector

	QUESTION TOPIC	HYBRID -- MARITIME & OFF-SHORE OIL MARKET SECTOR
1	**Production & Sales Growth**	• This market sector covers both off-shore oil rigs where SOTM terminals require tracking to compensate for platform movement as well as the ferry services supporting oil exploration activities.
2	**Growth by Market Sector. Why is land-based SOTM declining?**	• A sub-sector of this business encompasses commercial ferry boat traffic and serves the personal communications needs of passengers. This market segment continues to grow. • Market growth has declined as a result of depressed oil & a gas price which in turn has resulted is a temporary reduction in the demand for new satellite services. • Off-shore oil rig personnel typically work 12-hour shifts and demand significant bandwidth during their downtime for personal communications. • Bandwidth availability is seen by this market sector as a significant constraint for employee well-being. • Link performance (latency in excess of 600 ms) has degraded the ability of this communications option to process certain (banking) transactions.
3	**Inhibiting factors influencing SOTM market & sales growth**	• Costs to provide services vary widely by location from $26,000 per month to more than $55,000 in the Canadian maritime's (Nova Scotia). • It is now seen as a given that oil rig operators have to deploy extensive 2-way CCTV services to document rig status back to shore for evaluation by land based experts. Bandwidth availability negatively impacts these operations. • Some countries (e.g. Libya) require services to be routed over a terrestrial link from an oil rig for up-linking over an in-country satellite link. (Inhibits growth.)
4	**Which entities are driving the product specifications?**	• Operators in this market sector rely heavily on the expertise of system integrators in determining appropriate product specifications which leads to acceptable turn-key solutions. • Companies providing guidance on technical specifications include: Harris CapRock, RigNet, Schlumberger and Intellian as examples.
5	**Dynamics impacting product approval & regulatory standards?**	• Regulatory and service licensing requirements have a severe impact on the market, particularly for operations in 3rd world locations. Ghana was cited as one example where approval could require in excess of five months for approving a satellite link. These restrictions do not serve the market well where business commitments often have to be made within one month. • Operations in 3rd world locations often call for the use of approved equipment but are not uniformly specific in what standards are required. • This market sector has been negatively impacted by problems associated with cross-pol interference. This suggests operations involving non-approved equipment or improper equipment installation and operation.
6	**Impact when sub-standard equipment permitted in market?**	• Apart from the x-pol comment above, respondents to this question suggested that this was more of an impact on the integrators and manufacturers supplying equipment to the market. Problems resulting from sub-standard equipment would be resolved at that level.
7	**Product Integrity (large & small scale manufacturers)**	• Responses to this question were similar to those from question six above. Hypothetically equipment selection would include manufacturers from the region in which rig operations were to be conducted if this would be viewed favourably by the relevant licensing authority. (Korea and China were cited as examples.)
8	**Examples of product specification / other comments?**	➢ Product specification questions best addressed by the system integrators and service providers. This market tended to procure turn-key solutions. ➢ Respondent commented on re-certification requirements of some satellite service providers (e.g. Anatel-Brazil) // Fees for receiving product certification and general overall direction of ESA study to arrive at standardization / certification methodology for manufacturers providing equipment to this market sector.

Table 9: Top level responses from Off-Shore Oil Market Sector

	QUESTION TOPIC	LAND BASED -- MARKET SECTOR
1	**Production & Sales Growth**	• Some manufacturers / integrators perceive that the near-term demand for land based SOTM products and services have reached a plateau whereas others see this as a market with future potential. • Reasonably high volumes of Receive-Only RxO products continue to be deployed in the market but costs / equipment pricing for upgrading capabilities for Tx/Rx service represents a major challenge for achieving the required performance (no interference to adjacent satellite services) at commercially acceptable price points.
2	**Growth by Market Sector. Why is land-based SOTM declining?**	• Much of the recent growth in the demand for land based SOTM terminal hardware derived from military customers. This market has been in recent decline. • Some manufacturers are testing the market with offerings ranging from the provision of turn-key solutions to designs that capitalize on their core competencies and procuring the balance of the technology required to provide a turn-key solution. Examples included the in-house design and manufacture of the antenna and associated tracking system and the procurement of the ancillary equipment such as the HPA, LNA's and modems.
3	**Inhibiting factors influencing SOTM market & sales growth**	• Cuts in defence spending and the delays or cancellations of a number of European programs have contributed to the decline in the market sector for land mobile SOTM solutions. • Solutions for the military market are highly ruggedized and the associated terminal price points have discouraged growth in to solutions in to the commercial and private / personal market sector.
4	**Which entities are driving the product specifications?**	• A number of Integrators assembled solutions based on advertised product performance from sub-system manufacturers. As such there is a tendency to "trust" published hardware specifications. In the absence of adequate published data, integrators supporting the land based market segment often procured hardware based on internally developed specification requirements.
5	**Dynamics impacting product approval & regulatory stds?**	• The different requirements for accessing satellite services amongst different satellite operators is seen as a challenge that requires tailored design solutions or a more expensive design to handle the most challenging requirements. • Some respondents noted regulatory standards calling for requirements that had no bearing on adjacent satellite interference of the operation of the satellite link. • The practice followed by some satellite operators that calls for a periodic recertification, even if there no design changes to a particular product, is seen as adding needless cost to a product which is subsequently passed on to customers. • Topping the list for some participants was the speed and cost associated with securing equipment type approvals. For smaller companies that lacked in-house test facilities, the "red tape" for addressing these was seen as onerous.
6	**Impact when sub-standard equipment permitted in market?**	• Not a problem. • A number of participants in the market saw the imposition of requiring type approvals as the best mechanism for preventing sub-standard equipment from entering the market.
7	**Product Integrity (large & small scale manufacturers)**	• Major actors in this market segment do not perceive this to be a problem for their product offerings as many have to be qualified against military requirements as well as the satellite operator standards. The perception of the major actors is that low price (mom & pop) operations have not significantly penetrated the market due to the hardware qualification requirements.
8	**Examples of product specification / other comments?**	➢ Respondents tended to avoid answering this question where proprietary design solutions were involved. Most pointed to their open and published specification data sheets. .

Table 10: Top level responses from Land Based Market Sector

	QUESTION TOPIC	AIRBORNE -- MARKET SECTOR
1	**Production & Sales Growth**	• The airborne market sector offers one of the most dynamic growth areas • .Passengers see service as a requirement rather than a novelty.
2	**Growth in the airborne market sector**	• Market represents huge growth potential when considering number of commercial flights and the penetration of air travel in the industry today, • Some commercial airlines reported annual growth in excess of 120%. • One operator reported having 60,000 to 90,000 passengers in the air at one time.
3	**Inhibiting factors influencing SOTM market & sales growth**	• Capacity and service availability are seen as the largest constraints if growth continues at the high levels reported over the past one to two years. • With up to 600 passengers on an Airbus 380 the on-board systems can become overloaded and limits the number of passengers that can access services. • Many aircraft have a per channel bandwidth restriction of 432Kbps. • One commercial operator reported passenger demands exceeding 50 Gb on a single flight. • Current equipment may not have been designed to handle expected traffic volume. • Solutions need to be developed based on the market requirements. Equipment solutions for a global market may be different to a regional (North American) market.
4	**Which entities are driving the product specifications?**	• Traditional airline operators have not been good at understanding the industry needs and suppliers too appear to have misjudged the equipment requirements. • The cruise ship industry appeared to have learnt the equipment specifications and requirements the hard way and a number of airline operators have not benefitted from this experience. • Decisions have to be made regarding equipment solutions for a simple data service as opposed to broadband streaming media.
5	**Dynamics impacting product approval & regulatory stds?**	• International carriers noted that some countries (e.g. India & China) do not grant approvals. The conundrum is why when offering 802.11 services on an aircraft should a country below the flight be concerned how the connections are made, As example passengers can use in-seat phones over a Satcom link but are not allowed to access 802.11 internet services • The industry sees a need for developing globally recognized protocols that permit commercial service to be provided as aircraft pass through various national airspaces.
6	**Impact when sub-standard equipment permitted in market?**	• Qualification for equipment used in the airborne market sector calls for more extensive (airworthiness) certification than required by the satellite operators who impose their own standards. • Certification often takes more than one year and as a result airframe manufacturers take great care to pre-screen equipment to eliminate the need to change equipment vendors and avoid potential problems with low-cost, sub-standard equipment. • In the event a problem is encountered, a VAR would liaise with the manufacturer to develop a solution. This would then have to go through recertification.
7	**Product Integrity (large & small scale manufacturers)**	• Small vendors do not tend to participate in this market due to the “high cost of entry” caused lengthy interaction and design reviews required by the airframe (Boeing and Airbus) manufacturers. • Most suppliers to the SOTM market are on their second or third generation design. • Most antenna solutions utilize mechanical tracking although flat panel (phased array) designs are under development by several manufacturers
8	**Examples of product specification / other comments?**	➢ Specifications have not been available for general release. ➢ Some airline operators are developing generic system requirements based on “lessons learned” from prior experience. The GVF & FHG will continue to push the industry for more specific details regarding specification and standards requirements.

Table 11: Top level responses from Airborne Market Sector

QUESTION TOPIC		ADVANCED CONCEPTS TERMINALS -- MARKET SECTOR
1	**Production & Sales Growth**	• This grouping comprises advanced concepts designs employing phased array / flat panel terminal solutions. • One concept is based on "chip-centric" technology with rapid 10ms update times.
2	**Growth by Market Sector. Why is land-based SOTM declining?**	• It is expected that the land based SOTM market will continue to grow but not necessarily at the recent rates experienced by the industry. • Phased array and similar solutions offer the potential for tailoring pattern coverage to minimize denial of service from jamming or other intentional interference.
3	**Inhibiting factors influencing SOTM market & sales growth**	• One respondent noted that satellite operators had reported receiving ASI when accepting untested / unqualified equipment to access their services. The initial acceptance of sub-standard equipment confused the market for manufacturers that produced high quality equipment. • Another response called for the development of a well understood and well published set of rules governing specification SOTM specification requirements to reduce the confusion that exists in the market place. • It was suggested that the satellite operators as a group had failed to uniformly enforce the performance requirements needed to protect the QoS in Ku-band.
4	**Which entities are driving the product specifications?**	• Participants see the satellite operators as the primary driving force for SOTM performance specifications. This is because users of SOTM terminals are not necessarily experts in the technology.
5	**Dynamics impacting product approval & regulatory stds?**	• Multiple regulations have complicated the development of solutions for the SOTM market. Often cited were FCC 25.209, 25.222, 25.138, ITU 524 specifications and ETSI 302-286. Although these specifications call for a number of similar performance parameters the differences between the specifications complicates the design process for manufacturers. • Extracting the toughest requirements from each of the market place specifications (an approach being considered by Inmarsat) is seen as providing the highest performance products but this approach usually results in a cost penalty. • AsiaSat was referenced as having imposed strict off-axis e.i.r.p limits which had the effect of driving customers to lower cost / performance solutions.
6	**Impact when sub-standard equipment permitted in market?**	• SOTM customers tended to gravitate to higher quality and higher cost solutions following negative experiences with sub-standard equipment. • One SOTM manufacturer noted a decline in the number of low-end manufacturers in the UK and commented on the disproportionate number of small SOTM companies that had disappeared. • There appears to be a correlation between the long term survival in business and the product quality provided by a manufacturer..
7	**Product Integrity (large & small scale manufacturers)**	• Participants from this market sector are generally in the advanced stages of product development but have not penetrated the market with hardware. Expect this to change if their products meet technical performance expectations at competitive pricing. Actors in this market sector are currently being guided by the requirements of the satellite operators rather than prospective customers. They acknowledge that low end manufacturers seldom fully understand the system specifications and even less frequently submit their products for qualification.
8	**Examples of product specification / other comments?**	➢ The pattern performance for phased array and similar solutions degrades as the pattern is scanned off-axis. Manufacturers of these products question why the operators and regulatory agencies have imposed tough performance demands for regions well removed from the GSO where interference would be a major concern. No examples of product specifications, other than those published in promotional materials, were offered.

Table 12: Top level responses from Advanced Concepts Market Sector

QUESTION TOPIC		SATELLITE OPERATORS -- MARKET SECTOR
1	**Production & Sales Growth**	• Satellite operators in this group comprised AsiaSat, Eutelsat, Intelsat, Inmarsat and SES. These operators perceive the market as covering three areas: land, sea and air. Land is seen as a niche SOTM market which includes military communications. Maritime is seen as a mature but growing market and airborne represents a developing market with considerable potential.
2	**Growth by Market Sector. Why is land-based SOTM declining?**	• Military and government communications are currently driving the land based SOTM market. Uploading video and other critical information continues to represent the bulk of the growth in this market segment. • A predicted decline in the need for military communications over recent demands is seen as a primary contributor to a decline in the land based sector.
3	**Inhibiting factors influencing SOTM market & sales growth**	• With regard to the airborne SOTM market, the cost of service is seen as an influential market factor. The cost tends to be high for a few hours of service and is seen as a constraint for individual customers. • Available bandwidth is seen as a potential limitation if the market grows as some predictions imply. • The small size of airborne terminals is predicted to reduce link margins and represents a major concern to the operators in terms on increasing ASI levels. • Designing solutions that reduce ASI and associated hardware costs represents a major challenge influencing growth in the airborne SOTM market.
4	**Which entities are driving the product specifications?**	• The satellite operators see themselves as the primary driving force for establishing SOTM specifications. There has been general agreement in the specification requirements however different operators tailor requirements to fit their needs. • The Satellite Operator Subgroup (SOSG) has developed a set of minimum performance standards that they will accept – however these have not been released in the public domain. • The eventual plan calls for the GVF promoting these standards in the industry once they have been formally released by the SOSG. • Other entities Panasonic, ViaSat etc. have also been influencing SOTM specifications and so far the GVF has not been able to schedule a conference with these entities for inclusion in the ESA study.
5	**Dynamics impacting product approval & regulatory stds?**	• The current practice calls for individual satellite operators issuing their own SOTM type approvals. • A mix of SOTM type-approval procedures is in use ranging from acceptance of the terminal performance advertised in manufacturer literature to conducting tests on complete terminals. • One objective of the SOSG is to establish a more standardized approach for authorizing SOTM equipment to access satellite services. • The Minimum Antenna Performance Requirements defined by the SOSG will not have an impact on the minimum standards currently set by individual satellite operators. • Different satellite operators have different agreements in place with their neighbouring operators with regard to power (density) constraints
6	**Impact when sub-standard equipment permitted in market?**	• A common problem within satellite communications is the presence of unwanted signals. It can never be entirely eliminated, but can be reduced to a minimum. • Good practice calls for analyzing new antenna designs and verifying their performance prior to satellite access in order to anticipate possible problems. • Sub-standard equipment is often accompanied with the release of incomplete or inaccurate specification performance data sheets. This has resulted in interference and sub-standard performance on an intended satellite link.
7	**Product Integrity (large & small scale suppliers)**	➢ Manufacturers of quality products will look for ways to save production costs if sub-standard products continue to be permitted to enter the market. ➢ Specifications have to be clear to prevent a general degradation in QoS.
8	**Sample specifications**	➢ Most relevant will be the release of the SOSG Minimum Performance Requirements document.

Table 13: Top level responses from Satellite Operator Market Sector

Information has been extracted from the six tables in order to identify areas of concentration for completing the next study phase. We have excluded content over which the study is likely to have minimal influence. Examples here would include the impact of reduced military spending and the commercial practices followed by a number of third world countries who see regulation and the imposition of arcane standards and practices as a revenue generator for the country rather than enhancing the quality of service provided by the satellite link.

The responses are grouped by five market vertical sectors with each grouping being assigned a numerical value (one, three and five) indicating the importance or concerns for the vertical entity. A value of one signifies the least concern and a value of five signifies maximum importance. Assignment of a one-three-five value has been somewhat subjective and influenced by the amount of time a survey respondent wanted to dwell on a particular question during the interview process.

6.2.1 Factors Influencing the Regulatory and Licensing Environment

The regulatory environment to a large degree establishes the performance requirements for the manufacturer. The specifications are primarily established to prevent harmful interference. The ITU specifications form the foundation and essentially establish the minimum performance requirements. Individual satellite operators and governments often call for more restrictive performance where the potential for interference is of concern. This has resulted in many different specifications and regulations being imposed on the market. Satisfying each of these specifications has a direct impact on the manufacturers, the time required to introduce new products and the eventual hardware costs for customers deploying SOTM terminals. A manufacturer is faced with a business decision whether to design products to meet “all global specifications” or to tailor designs for niche market sectors which may have lower level requirements.

The factors identified in table 14 identify the major concerns with regard to the regulatory environment and the barriers for developing SOTM products and promoting them in the market.

FACTORS INFLUENCING THE REGULATORY AND LICENSING ENVIRONMENT	Satellite Operators	Maritime Mrkt	Land Mrkt	Airborne Mrkt	Special Products
POTENTIAL BARRIERS TO BUSINESS					
➢ Plethora of different regulatory requirements causes problems for manufacturers and customers when seeking to operate SOTM terminals in different regions. This condition exists in advanced countries and to a lesser degree in third world nations. The result is that no one terminal design offers the most cost effective solution for all cases. Manufacturers are forced to offer several versions of a design to attain optimum solutions at the most competitive price points. This does not permit optimum terminal pricing to be achieved through volume of scale.	3	5	1	5	1
➢ Developing regions and third world nations often see licensing as a revenue generator with little benefit for the quality of service. As a further revenue generator some countries require satellite services be up-linked from in-country, government owned facilities. This is a concern for the oil and gas industry and requires that terrestrial services be established to link off-shore operations with an in-country hub station.	3	5	1	3	1
➢ Operations for SOTM terminals differ considerably for the type of service being provided. In the case of land based terminals the operations may be limited to one country or region. By comparison, the bulk of maritime operations would take place in international waters with minimal licensing restrictions. The exception would be for oil rig operations in coastal waters. The most challenging environment is found with SOTM services for the airborne market sector where international flights require operations in multiple airspaces.	1	5	1	5	3
➢ Time to process licenses varies greatly by region and can take as long as five months for some markets – particularly in the oil and gas industry. SOTM terminal performance not uniformly specified which suggests different levels of approval when seeking operations in different regions. For the airborne market sector, the industry lacks consistency in approving the operations of SOTM terminals. China and India were cited as examples of where the government regulator called for airborne services to be first downlinked to a ground station before up linking traffic to a satellite.	3	5	1	5	1
➢ The evolution of advanced SOTM designs (using phased array and similar antenna solutions) has complicated the design process for manufacturers due to the variety of specifications in place to satisfy current regulatory standards. This drives the design choice to specific solutions depending on if a product has to satisfy the different requirements found in ETSI 301-286, FCC 25.209, ITU-R 524, FCC 25.225, FCC 25.138 and others. The choice for a manufacturer is to tailor the design to a compilation of the most restrictive standards (resulting in expensive solutions) or to lower standards (resulting in application unique, less expensive solutions).	1	3	5	5	5

Table 14: Factors Influencing the Regulatory and Licensing Environment

6.2.2 Factors Influencing Terminal Qualification and Certification

The challenges facing the qualification of SOTM terminals are extensive. Consolidated feedback from the market survey has captured the major concerns.

Foremost is the number of different specifications facing a manufacturer followed by the lack of an accepted and recognized test procedure to conducting type approval tests. In response to industry concerns, the GVF (with consensus from the SOTM market sector) has developed test procedures to address the concerns of the industry. These are contained in GVF document GVF-105, “Performance and Test Guidelines for Type Approval of Coms on the Move Mobile Satellite Communications Terminals”. The document has been enhanced by the inclusion of motion profiles resulting from the work undertaken by Fraunhofer IIS in support of the ESA ARTES activities and includes profiles for maritime and land-based environments. It is anticipated that airborne and high speed rail motion profiles will be included in future document revisions.

As noted elsewhere in this document, the satellite operators have not reached consensus on the performance requirements for SOTM terminals accessing their services. In order to address this issue, the focus of GVF-105 has been to reach agreement on the test methods permit the results from any type approval activity to be compared against the performance requirements for a specific satellite operator or regulator. GVF-105 remains flexible for the inclusion of different motion profiles covering markets in to which EU nation members may promote their products. The challenges in reaching a consensus were recognized at the last ESA design review when it was agreed that GVF-105 would be structured for recognition by all interested parties on the test methods to me employed.

Another factor challenging the execution of SOTM terminal type approval tests is the availability of acceptable test facilities. The Fraunhofer IIS Facility for Over-the-air Research and Testing FORTE at Ilmenau represents the state of the art for conducting these tests and has been designed specifically for SOTM terminal measurements. It is unique. Open field testing, where SOTM terminals are driven around a track or installed on a maritime platform can accommodate testing but are penalized by not being able to provide a repeatable test environment. The FORTE facility solves this problem. One restriction that may be encountered by the FORTE is the ability to conduct type approval tests if the size of a SOTM antenna violates the accepted $(2D^2)/\lambda$ far-field test conditions. The availability of suitable test facilities may introduce a bottle neck in to type approval activities and delay qualification of new products for the SOTM market.

The factors identified in table 15 illustrate the major concerns for the product qualification / type approval environment. Product qualification is seen by many manufacturers as a differentiator for their products and the resulting delays in achieving approval is seen as barrier to business development.

SOTM TERMINAL QUALIFICATION AND CERTIFICATION	Satellite Operators	Maritime Mrkt	Land Mrkt	Airborne Mrkt	Special Products
POTENTIAL BARRIERS TO BUSINESS					
➢ Industry lacks uniform performance standards against which products can be qualified. Regulatory and national agencies have developed standards that call for different performance levels. Likewise the satellite service provider community has identified different performance levels for products accessing their services. A satellite operator subgroup comprising Inmarsat, Eutelsat, AsiaSat, SES and Intelsat was organized under the GVF-MRA to develop performance specifications that each of these operators recognized as satisfying the minimum equipment performance for accessing their services. While this group has made admirable headway in developing (harmonized) performance requirements, their work is still restricted by an NDA and cannot be released until consensus is reached within their individual organizations.	5	5	5	5	3
➢ Availability of suitable test facilities limited for conducting SOTM terminal qualifications. Apart from the FHG facilities in Ilmenau all other known facilities require support from a cooperating adjacent satellite operator to determine pointing and tracking accuracy.	3	5	5	5	3
➢ SOTM terminals that employ traditional SOTM manual tracking are easier to qualify than phased array solutions. The added complication for phased array and similar designs results from the volume of data required to characterize the terminal performance as a result of antenna patterns and gain that change as a function of scan and skew angles.	3	5	1	5	3
➢ Qualification of smaller (sub 1-meter) terminals present challenge to the industry as a result of the broader main beam antenna pattern violating the sidelobe mask imposed by many satellite operators and some regulatory agencies. Solutions calling for waivers require additional analysis and justification on the part of the applicant and are often rejected by satellite operators as a result of the general increase in background interference as increasing numbers of terminals are deployed.	5	5	3	1	1
➢ Although the majority of satellite operator members of the GVF have subscribed to the mutual recognition process (wherein the test results independently witnessed by a GVF ATE or satellite operator representative) common practice shows that a number of these operators still require the tests to be conducted at their facilities. This restriction adds time to the qualification and certification process as well as to the cost to the terminal manufacturer or license applicant.	3	5	5	5	5

Table 15: Factors Influencing Terminal Qualification and Certification

6.2.3 Issues regarding product promotion in the SOTM market

Satellite operator specifications are often seen as a challenge to business for the manufacturer. From an opposite standpoint, the challenge for the satellite operator is the way in which manufacturers promote their products. Manufacturer's specification data sheets vary widely in how the performance of products is defined and this has presented serious problems for some operators. Several examples are included here to illustrate the point. How is the gain of a SOTM terminal antenna defined? Is it a mid-band value? Does it reveal minimum gain values that might be encountered across a given band? Is the gain referenced at the input flange to the antenna or at the radio flange in which case OMT and TRF losses would be included? Is the gain advertised with or without a radome? Other factors may include (but limited to) the list below

- Pointing Error Threshold (above which transmission is muted within 100ms).
- Minimum G/T (across Rx band and including pointing loss when miss-pointed by the error threshold).
- Minimum EIRP (across Tx band and including pointing loss when miss-pointed by the error threshold).
- Maximum On-Satellite EIRP spectral density for Low Mid and High frequency across Tx band (While compliant with ITU-R S.524-9 for off-axis EIRP spectral density emissions and including radiation pattern shift corresponding to miss-pointing by the pointing error threshold).
- Min. Rx X-Pol isolation (within pointing error Threshold)
- Maximum Cross-Pol EIRP spectral density (within pointing error threshold).
- Standard Motion Profile tested (i.e. Maritime Class A…)
- Availability (as defined by the percentage of time the system under test did not exceed the pointing error threshold when subjected to the standard motion profile).

Table 16 captures a number of points expressed during the survey process.

The inconsistencies in manufacturer's advertised performance data is seen as more of a problem for the satellite operator community, but many of the higher quality manufacturers expressed a desire for a "level playing field" wherein products in the market place can be compared on an equal footing with "clarity" in what the performance claims mean.

MARKET PROMOTION OF SOTM TERMINALS	Satellite Operators	Maritime Mrkt	Land Mrkt	Airborne Mrkt	Special Products
POTENTIAL BARRIERS TO BUSINESS					
➢ Poor consistency in specifying products has led to confusion in the market place for satellite operators planning service links. Much of the performance contained in manufacturer specifications is ambiguous which challenges the satellite operator to offer product recommendations to customers seeking services on their satellites	5	3	3	5	1
➢ High quality manufacturers have expressed an interest in standardizing the definitions regarding how products are specified. This is perceived as a way for them to differentiate their products from those with lower performance.	5	5	5	5	1
➢ Product type approvals seen by the satellite operators and high quality manufacturers as a preferred way to minimize confusion that is prevalent in the SOTM market.	5	5	5	5	3
➢ Many product procurements are made with an emphasis on the lowest terminal price with performance and compliance to regulations being a secondary concern. Products procured under this dynamic create an interference concern for satellite operators and a tendency for terminal manufacturers to reduce performance, quality and reliability in order to compete in the market.	5	3	3	5	1
➢ The design review process in the airborne market tends to eliminate confusion in performance claims. Major manufacturers such as Airbus and Boeing conduct exhaustive reviews throughout the development phase of any aircraft development and the cost of this activity encourages full exposure of the performance of all of the systems incorporated in the aircraft. The certification process can take in excess of one year and the cost of having to requalify a non-compliant product is significant.	3	na	na	5	1
➢ Manufacturers engaged in developing non-traditional product solutions for the SOTM market have to this point made significant claims regarding product performance without supporting test documentation. While phased arrays and similar solutions are well suited to high speed (airborne) applications, the physics of these solutions anticipates challenges in meeting satellite operator and regulatory requirements for currently specified performance parameters	5	3	3	3	3

Table 16: Factors Influencing Promotion of Terminals in the SOTM market

6.3 Initial recommendation of SOTM standards

After the milestone 1 review meeting at ESA-ESTEC facilities, the objective of this study was modified with ESA concurrence. The input received during the meeting from the satellite operator community shows that reaching consensus regarding standards and specifications for the SOTM market is not possible.

Fraunhofer IIS together with GVF and ESA proposed modifying the objective of the study being to recommend and develop standardized test conditions and procedures to validate the performance of the SOTM terminals and to gain industry acceptance of these procedures for equipment type approvals. During the milestone 1 review meeting, the new objective met wide acceptance from the attendees, especially the satellite operators including Eutelsat, Inmarsat, SES, O3b and Hispasat. Moreover, the outcome of implementing the consultation plan (WP3200) consolidates this wide agreement.

It is reported that having a standard procedure for type approval and product qualification is one of the biggest transaction needs for the SOTM market (cf. Table 15). Standard test and type approval procedures are seen as the way for having basis for fair comparison between different products and they will help to remove confusion. On the other hand, the GVF satellite operator sub-group SOSG including AsiaSat, Eutelsat, Inmarsat, Intelsat and SES has defined minimum performance requirements for SOTMs. These requirements will be recognized by each of the individual operators.

The standardized test procedures are to be used to verify the performance of a SOTM terminal with respect to the minimum performance requirements defined by the SOSG or any other elaborate specifications defined by the individual operators where it will be left for the operator to decide if the product performance is acceptable.

The test procedure described in the document GVF-105 has been updated by Fraunhofer IIS and GVF and validated in a comprehensive test program. **GVF and Fraunhofer IIS believe that GVF-105 is ready to be promoted for conducting formal type approval activities.**

7. SOTM Standard Recommendation

Task 4 of this study formulates its target objective. Based on the outcomes of the consultation plan (Task 3), a recommendation of how to test SOTM terminals using standard type approval procedures was developed. The details of the recommended standard type approval are presented in this chapter.

7.1 Standard Test/Type Approval Procedures

Standard type approvals must provide procedures to test the performance of the different parts of the SOTM terminal. A fair basis for comparison represented by well-defined metrics is necessary. The following four aspects are essential and they formulate the core of the proposed standard type approval program.

1. **Exposure to mobility:** standard motion profiles are missing in all all existing type approval specifications, although they are believed to be a major element. Standard motion profiles are essential to provide fair basis for comparing the performance of different SOTM terminals. A terminal with well performing tracking unit can be tested on a rough terrain or in tough sea conditions in which it will fail to meet the pointing requirements. Another poor performing terminal can be tested on a relatively easier motion profile on which it will succeed to meet the pointing requirements and will be approved accordingly. Fraunhofer IIS defined standard motion profiles for the land mobile as well as the maritime environments in the scope of the ESA ARTES 5.1 project titled "Characterization of the Mobile Tracking Needs (CCN2) // contract 4000103870/11/NL/NR". The standard motion profiles were included in GVF-105 recommendations and type approval guidelines. It was stated that a terminal is to be tested in a facility where replaying the standard motion profiles is possible or in a free field where the statistics of the used motion track and the statistics of the standard motion profiles should match.

2. **Metric for judging pointing performance:** Fraunhofer IIS operates the Facility for Over-the-air Research and Testing FORTE which enables accurate measurements of antenna de-pointing. A sensor

array mounted on an antenna tower is used to measure the antenna pattern at different points in space. By correlating the antenna pattern with the transmit signal from the SOTM antenna while being on the move, accurate antenna de-pointing is estimated. This method is well suited for antennas with fixed beam patterns, e.g. dish antennas, however, the development of SOTM terminals is moving towards the deployment of phased arrays instead of dish antennas. For phased arrays, it is very challenging and almost impossible to measure all possible antenna patterns. As a result, the estimation of antenna de-pointing and the evaluation of the terminal's pointing performance are difficult. A measurement in a free field is still possible, although, the exact de-pointing estimation is not possible and only measures like Adjacent Satellite Interference ASI are the only way. The state-of-the-art measurement laboratories and test fields do not provide a solution for measuring the exact antenna de-pointing of phased arrays. In Section 7.4, an extension of the current structure of FORTE based on increasing the number of sensors on the antenna tower is described. This extension will enable the measurement of the main beam and the first side lobes of the radiation pattern. This will enable the online de-pointing estimation of phased arrays.

3. **Gain and EIRP mask conformance:** The test plans included in the GVF-101 document are believed to be comprehensive for measuring the antenna gain contours. The different angular cuts and raster scans which are needed to fully characterise the antenna pattern are defined. In the proposed standard type approval plans, the tests in GVF-101 are adopted. The gain/ESD mask specified by the relevant satellite operator is then used to verify the conformance.

4. **Network performance:** based on the manufacturer/operator request, a SOTM modem is connected to the antenna and traffic tests are performed. Normalized data throughput is to be used as a metric to judge on the network performance.

In Section 7.2, we will discuss the different possibilities of how a SOTM terminal is currently tested. It is always preferable to have a controllable test facility which is able to evaluate the performance of the different components of the SOTM terminal according to the proposed standard type approval procedure.

7.2 State-of-the-art SOTM testing facilities and environments

Testing SOTM terminals is conducted, so far, either by modem tests in a laboratory or as free field tests with the complete system. For the laboratory testing of modems the communication stations are connected via cables to channel emulators. With these emulators all channel parameters that are of potential influence to the system can be set and replayed repeatedly, either combined or as individual effects, as is also described in [1]. A setup with such a channel emulator enables testing of a variety of parameters affecting the modems behaviour (e.g. fading, Doppler shift or multipath effects), but completely bypasses the terminals antenna and its tracking system. As the pointing accuracy and tracking performance of the antenna system has a massive influence to the link quality, this aspect cannot be left aside in case of system performance evaluation. For that reason, the terminal has to be tested under real-world conditions incorporating the antenna and it's tracking systems. The common approach to do so is to perform these tests in the free field. In that test case the terminal is mounted on a vehicle, which drives along a certain test track. Meanwhile, the terminal communicates via a real operational satellite to a master station. These tests are commonly known and are conducted at various locations, as was described in [2] and [3]. Although motion and antenna systems are included in these tests, this approach suffers from critical drawbacks. At first, the environmental parameters, e.g. fading or motion, cannot be separated from each other. This means, in the post analysis the influence of a single parameter cannot be precisely determined. A second source of uncertainty is the lack of reproducibility of the same test scenario, since the identical track will never be met a second time, neither the same lanes nor at the same speed. In addition, the environment may also change when conducting the test for the second time. However, identically repeated tests are always important during the design phase of a terminal, to check if the system behaves differently than before.

To overcome these drawbacks, SOTM terminal tests need to be conducted in a fully controllable environment, i.e. a far-field test range that emulates motion, the satellite and the LMS channel. A test range similar to that, utilizing a three-axis motion emulator is already available at Aberdeen Proving Ground (APG), Maryland, USA [4]. At this site, the terminal is tested indoors for precise antenna measurements (only in near field) and outdoors for testing with operational satellites. However, a complete test of the terminal in the far-field with reproducible and well defined LMS channel parameters is not possible, since the system is always subject to the current weather situation. Moreover, other multipath environments (e.g. urban or sub-urban) cannot be emulated at all. FORTE offers the full capabilities manifold of a controlled test environment for SOTM terminals. FORTE combines the advantages of being:

1. a laboratory environment offering repeatable and controllable conditions for the whole SOTM terminal
2. operating in the antenna far-field and emulating real (standard) motion profiles such as being in a free field

Up to this moment, we are not aware of any facility similar to FORTE. Table 17 summarize a number the existing facilities in the market and comparing them w.r.t. the ability to provide the requirements of the standard test procedures proposed in the context of this study.

The GVF at the request of various satellite service providers has started to assemble a global directory listing antenna test facilities which would be useful for qualifying SOTM terminals. Unlike the FORTE and Aberdeen Proving Ground test facilities, not all test facilities are capable of completing all of the qualification tests required to certify a SOTM terminal. This could require that an applicant seeking type approval to conduct tests at multiple facilities. The majority of facilities listed in table 17 would be restricted to conducting antenna pattern measurements. Full SOTM product certification would then require additional tests at a secondary facility to evaluate the terminal tracking accuracy and its ability to mute the up-link signal if tracking accuracy exceed specified limits in excess of specified times. Tracking accuracy tests could be performed by placing the terminal on a motion table and monitoring signals received on adjacent satellites. This form of testing would require accurate pattern measurements for the terminal before conducting live satellite tests. An alternate approach may be to utilize a ground based satellite emulator and position a laser at a strategic location on the terminal to monitor movement as the motion table exposed to terminal to various motion profiles.

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	TEST FACILITY NAME	LOCATION	COMMENTS
1	**Fraunhofer Forte Facility**	Ilmenau, Germany	Test facility designed specifically for conducting all aspects of SOTM terminals qualification measurements in a using repeatable dynamic motion profiles
2	**Aberdeen Proving Ground**	Aberdeen MD, USA	Location for renowned Churchville test track. Provides extensive capabilities to conduct outdoor SOTM terminal measurements. Capabilities extend well beyond those required for tracking accuracy terminal evaluations.
3	**Qinetiq Funtington (formerly ASWRE)**	Bosham UK	Extensive antenna pattern test facilities using far field out door range as well as indoor anechoic chamber. Measurement test capability HF through 60 GHz
4	**Queen Mary Antenna Measurement Labs.**	London, UK	Compact antenna range. Suitable for small, lightweight antenna terminals.
5	**Combitech**	Arboga, Sweden	Large outdoor range. Suitable for testing heavier antenna terminals for satellite bands through Ku-band. Capabilities at Ka-band not known.
6	**Raytheon**	Multiple locations in USA. Antenna test facilities located in Waltham MA and El Segundo CA.	Multiple ranges comprising anechoic chambers (far-field configuration) and Near Field and Compact antenna test facilities. Measurement capabilities cover all satellite frequency bands up to 110 GHz
7	**European Space Agency**	Europe	Large compact range providing quiet zone measuring ~1.2m x 1m x 1m. Range uses dual reflector antenna arrangement and supports AUT loads up to 100Kg. Operational frequency range ~ 4GHz – 250 GHz.
8	**Catapult Satellite**	UK (Various locations)	Equipped with comprehensive microwave test facilities including outdoor antenna pattern ranges. Company has participated in ESA projects.
9	**ProBrand International**	Locations in the USA and UK.	Operates large compact range located in Atlanta. Facility extensively used for VSAT measurements in Ku and Ka-band frequencies. Supports AUT loads up to ~ 45Kg (100lb). Five axis positioner (Roll/manual off-set/ El/ Az & floor slide.) Measurement frequency range covers ~ 2GHz through 40 GHz.
10	**Cobham**	Chevely, UK	Operates Spherical Near Field range covering frequency range of ~ 0.4 to 30 GHz. Company has been involved in the design and testing of COTM products and is believed to have an outdoor range from acquisition of another company.
11	**Rhode & Schwarz**	Memmingen, Germany	Advanced anechoic test facility for radiation pattern and other antenna measurements covering a frequency range of ~200MHz through 40 GHz. The 8-axis positioning hardware will support loads up to 200Kg

	TEST FACILITY NAME	LOCATION	COMMENTS
12	**Naval Research Laboratory**	Wash DC. , USA	Multiple anechoic chambers including compact ranges covering majority of satellite bands of interest. One large chamber equipped with motion table.
13	**General Dynamics Satcom Technologies**	North Carolina & Texas locations, USA	Multiple outdoor far field test ranges covering satellite frequency bands through 30 GHz. Texas facility used ground based satellite emulators for evaluating tracking accuracy.
14	**EADS Astrium**	Munich, Germany	Spherical and Near Field test facilities covering frequency range from ~ 1GHz through 40 GHz. Beam pointing accuracy to 0.01 deg. Supports heavy loads up to 5,000 Kg.
15	**France Telecom-R&D**	La Turbie Site, France	Far-field outdoor range (path length 1450meters) covering operational frequency range 0.5GHz to 50 GHz. Angular accuracy of 0.02 deg. Additional ranges include an outdoor near-field range and indoor anechoic chamber .
16	**Combitech**	Arboga, Sweden	Large outdoor range. Suitable for testing heavier antenna terminals for satellite bands through Ku-band. Capabilities at Ka-band not known.
17	**Technical University of Denmark. (DTU-ESA Facility)**	Copenhagen, Demark.	Facility equipped with large anechoic chamber to handle test articles up to 6 meters diameter. Operational frequency range up to 40 GHz. Maximum AUT weight limit is ~250Kg.
18	**Canadian Space Agency**	Ottawa, Ontario, Canada	Multiple RF test facilities. The Antenna Test Facilities comprise the Antenna Test Facility 1 (6x6), Antenna Test Facility 2 (12x12), Cylindrical Near-Field Facility, Spherical Near-Field Facility and the Rooftop Antenna Range. Spherical and cylindrical near-field radiation patterns are acquired indoors and with subsequent data processing, far-field antenna characteristics are derived. Frequency coverage up to 50 GHz.
19	**AvL Technologies**	Ashville, NC USA	Fully equipped facility for recording antenna patterns for all satellite bands of interest through Ka-band.
20	**BTP Systems**	Ludlow, MA., USA	Indoor test facilities comprising a compact antenna range and near field antenna range covering frequencies up to 50 GHz. Facility has been involved in qualification of SOTM terminals for airborne and maritime applications
21	**Aerospace Testing Facilities in India.**	Bangalore & Hyderabad, India	**DRDO**-Planar Near Field ranges with operational frequency to 18GHz. Perform customary antenna radiation pattern and XPD measurements. **EICL –** Compact antenna test range with capability to test antennas up to 2.4m through Ku-band
22	**Boeing Electromagnetic Testing Services**	Multiple locations, USA	Boeing Electronics offers a variety of antenna testing services utilizing small and large compact ranges and nearfield ranges. The company also provides outdoor far field test range services. Most upper frequency test capabilities attain frequencies of 50 GHz and 100 GHZ for limited applications.

Table 17: Potential test facilities for characterising SOTM terminals

The cost and time required to complete type approval testing depends on a many factors; a number of which are listed below:

- The primary factor is the level of detail required by each satellite operator to properly characterize and document ESIM terminal performance to the requirements of the particular operator. Variables include the number of test samples for evaluation along with the terminal parameters to be tested. For example, not all operators call for G/T or wind load testing. As a minimum, ESIM terminals would be qualified against the following parameters. Electrical testing includes: antenna patterns, gain, XPD and ASI. Mechanical testing for various motion profiles includes: tracking and pointing accuracy, transmit inhibit functions if the terminal mis-points beyond prescribed angular and time limits and skew tracking accuracy. Not all commercial test facilities have the ability to conduct each of these tests. This could then require a product to undergo testing in multiple facilities in order to satisfy the full suite of tests required by a particular satellite operator. The industry test procedures outlined in GVF-101 and GVF-105 have been recognized by the satellite operators for identifying the methods by the satellite operators for product qualification.

- A secondary factor is the level of automation regarding the setup for conducting the type approval tests and data acquisition capabilities. Some facilities, such as those found at Fraunhofer, have been designed for specifically conducting ESIM terminal RF and tracking accuracy measurements using a single AUT test fixture. Other facilities require RF pattern measurements to be conducted on an antenna range followed by relocating the AUT to secondary “set ups” for open field tracking accuracy testing. Open field testing often requires the cooperation of adjacent satellites or terrestrial based satellite emulators to complete the tracking accuracy evaluations for various motion profiles.

- Test requirements for military ESIM terminals may call for additional testing beyond the requirements for the satellite operators. These tests could include (i) shock and vibration testing (ii) climatic characterization including humidity and temperature (iii) effects of salt spray and blowing sand as well as biological factors including fungus.

- The design selected for an ESIM terminal can also have a profound impact on the time and cost for conducting type approval tests. The focus of the Fraunhofer / GVF study has been on traditional terminals involving mechanical tracking means used for qualifying the tracking / pointing accuracy. These designs have stable antenna patterns which are not influenced by the direction in which the terminal antenna is pointed in order to maintain the link. New technologies are evolving using phased arrays for ESIM terminals. These terminals are lightweight, low profile and can track at high angular speeds. The challenge however for these terminals, is that their radiation patterns changes and degrades from peak performance as the pattern is scanned away from the optimum performance conditions. This characteristic requires additional pattern testing to properly characterize the terminal over its range of tracking limits.

All of the above factors influence the cost that can be expected for qualifying an ESIM terminal and all combinations are beyond the scope of this study. At present, mechanical tracking solutions are used for the majority of ESIM terminals found in the market. Qualification testing for these terminals, when using a highly automated test facility, can usually be accomplished within a two-week time frame. The price for conducting the test program, including preparation of required test reports by Fraunhofer is nominally €25,000. This price would require adjustment if unusual conditions were encountered during a test campaign or if follow-up testing were required. At the upper extreme, some have reported the cost of conducting terminal qualifications to the ARSTRAT procedures outlined in the "Wideband X and Ka-band Performance Certification Test Procedures" document, dated April 2, 2016, to be well in excess of €500,000. The ARSTRAT testing calls for many additional tests to those described in GVF-101 and GVF-105. We have included reference to these requirements because Inmarsat has reported accepting ARSTRAT certified terminals in to the Inmarsat network without calling for additional testing.

7.3 The Fraunhofer Facility for Over-the-air Research and Testing FORTE and GVF-105 validation

The standard type approval procedures were included in GVF-105 recommendations and type approval guidelines. FORTE was proposed as the State-of-the-art testing environment which enables performing the proposed type approval procedures.

In this Section, the capabilities of FORTE are explained. It will be shown how the test procedure of GVF-101 and GVF-105 can be performed comprehensively at FORTE. As an Authorized Test Entity ATE of the GVF, FORTE offers an environment for testing SOTM terminals under realistic conditions. It was built by Fraunhofer IIS in collaboration with the Technische Universität in Ilmenau, Germany. FORTE has the ability to emulate the complete SOTM reality on earth without the involvement of operational satellites or real motion platforms (vehicles). Hardware in Ku- and Ka- frequency bands mounted on a 50 meters antenna tower is used to emulate the operational GSO satellite.

The terminal under test is fixed on a 3-axis motion emulator which can replay the movement introduced by the vehicle. A channel emulator reproduces both the fading caused by obstructions to the Line-of-Sight (LoS) and the one caused by adverse weather conditions. Moreover, a GPS emulator is available to be used for terminals which need GPS lock.

A block diagram with the full structure of FORTE is shown in Figure 4.

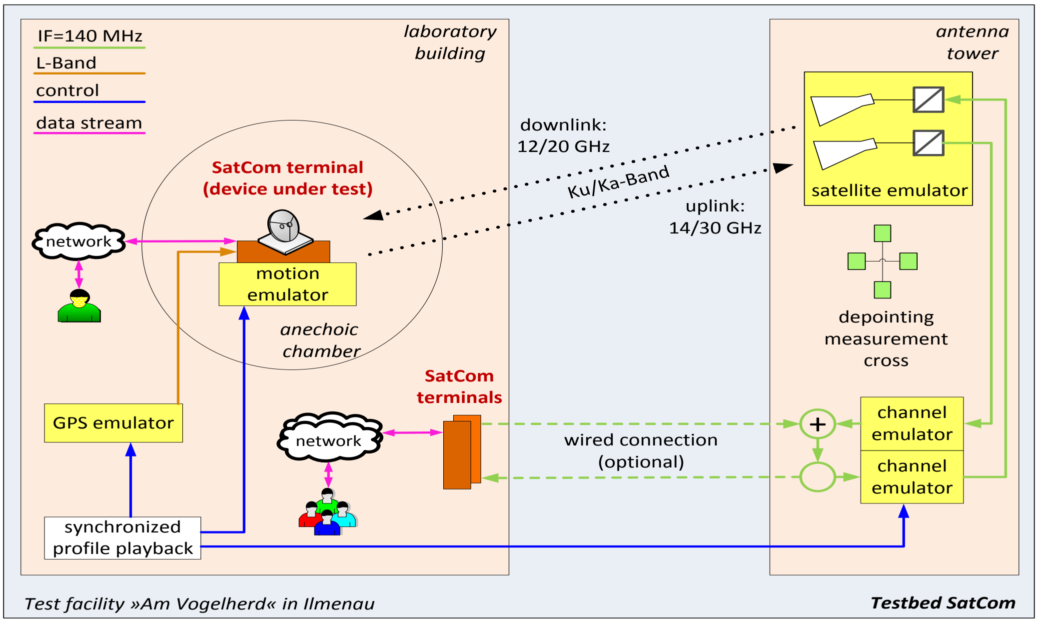


Figure 4: components of the Fraunhofer Facility for Over-the-air Research and Testing FORTE

The distance between the terminal and the antenna tower is about 100 m. This distance allows for far-field tests for most high gain antennas (e.g. dishes with up to 90 cm diameter in Ku-band, or 70 cm in Ka-band). The structure at FORTE enables also for XPD measurements in far-field.

FORTE compared to the traditional testing approaches which use operational satellites, yields the following advantages:

1. A higher accuracy in evaluating pointing errors.
2. Independence of the weather and of the satellite availability.
3. Allows for repeatability, while choosing any arbitrary parameter set (motion profile, fading profiles, etc.).

Testing/Validating SOTM terminals at FORTE according to GVF test recommendations

The proposed standard type approval procedures were validated at FORTE using a commercial off- the-shelf maritime SOTM. The tests have been witnessed by the manufacturer as well as by GVF. The antenna has a 60 cm dish and is operating in Ku-band. It is equipped with a 3-axis tracking unit, to be able to track in azimuth, elevation and skew. Figure 5 shows an exemplary SOTM antenna as it is mounted on the motion emulator while being tested at FORTE. A picture of the commercial antenna under test is not shown due to confidentiality reasons.

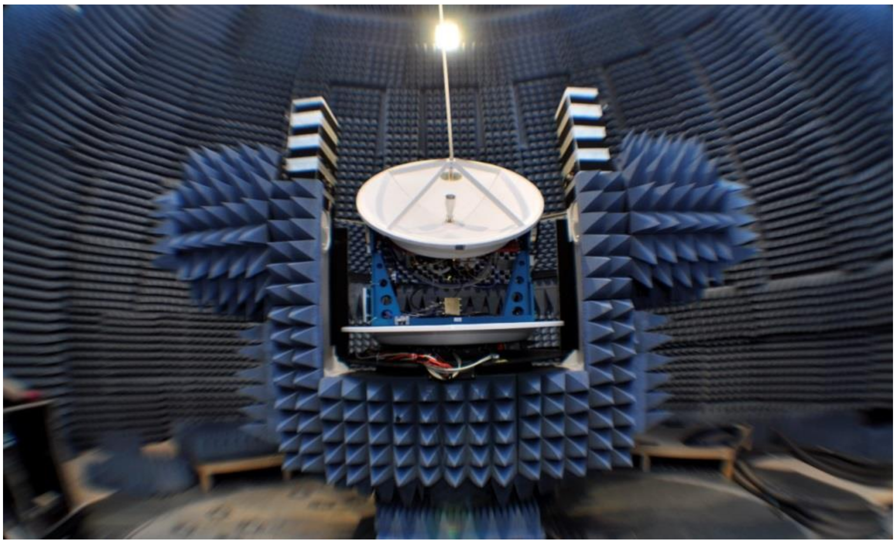


Figure 5: An exemplary SOTM antenna while being tested at FORTE

The GVF-101 and GVF-105 documents do not specify operational limits and it is left open for the satellite operator to decide if the performance of the SOTM terminal is accepted. After the agreement with the manufacturer, the performance specifications of EUTELSAT were applied and considered during the measurement campaign. The documents EESS502 and ESOG-120 from EUTELSAT specify the requirements which a SOTM terminal has to fulfil to get type approved.

The test results showed that the antenna did not fulfil the specifications of EUTELSAT and that it cannot be type approved accordingly. The procedures described in the GVF-101 and GVF-105 documents were validated during the tests and proved to be valid for type approving SOTM terminals.

7.3.1 Brief summary and test conclusions

Mask conformity

The measured patterns prove that the antenna under test does not fulfil the EUTELSAT gain mask specifications. In almost 25% of the cases, the EUTELSAT EESS mask was violated and the percentage over mask exceeds 10%. Moreover, the relaxed mask with 3dB and 6dB margins was also violated.

Tracking performance

According to the Q99 of the de-pointing estimation, the antenna under test fulfils the de-pointing requirements specified by EUTELSAT. In other words, for the maritime standard motion tracks, the antenna de-pointing does not exceed 0.4° for 99% of the time. If the Q100 is to be considered, the antenna is fulfilling the EUTELSAT requirements only for the maritime Class B motion track.

Mute functionality

According to the measured performance, the antenna under test does not comply with the basic regulations of mute performance. FCC 47 CFR §25.226(b)(1)(iii) states that if antenna de-pointing exceeds 0.5° the antenna has to cease transmission within 100 msec. In almost all cases, the antenna does not comply with this limit.

On the other hand, according to the specifications of EUTELSAT, the antenna has to mute before T seconds if it exceeds 0.4° of de-pointing. T is specified by the manufacturer and should not exceed 5 seconds in any case. According to this definition, the antenna is fulfilling the EUTELSAT mute specifications.

7.3.2 Verification of Co-Polar and Cross-Polar off-axis emission levels and mask conformity

The 3-axis motion emulator at FORTE is used not only to replay motion profiles but also to measure antenna patterns. Whether being 2D raster scans or principle plane cuts, the pattern can be plotted against any regulatory gain or EIRP mask. The approval criteria defined by the corresponding satellite operator can be verified.

Figure 6 shows one of the azimuth plane transmit cuts of the tested commercial maritime antenna. The azimuth cut is measured at antenna elevation 30°, frequency 14 GHz, Tx-Polarization H and Radome rotation 0°. These parameters are then altered according to what is specified in the GVF-101 and all required patterns are measured.
To check the off-axis emissions according to the specifications of EUTELSAT, the gain masks specified in the document "Earth Station Minimum Technical and Operational Requirements EESS 502" from EUTELSAT are plotted in Figure 6. The off-axis emission approval criteria of EUTELSAT can then be applied for the Co-Polar as well as the Cross-Polar patterns and a final conclusion can be drawn.

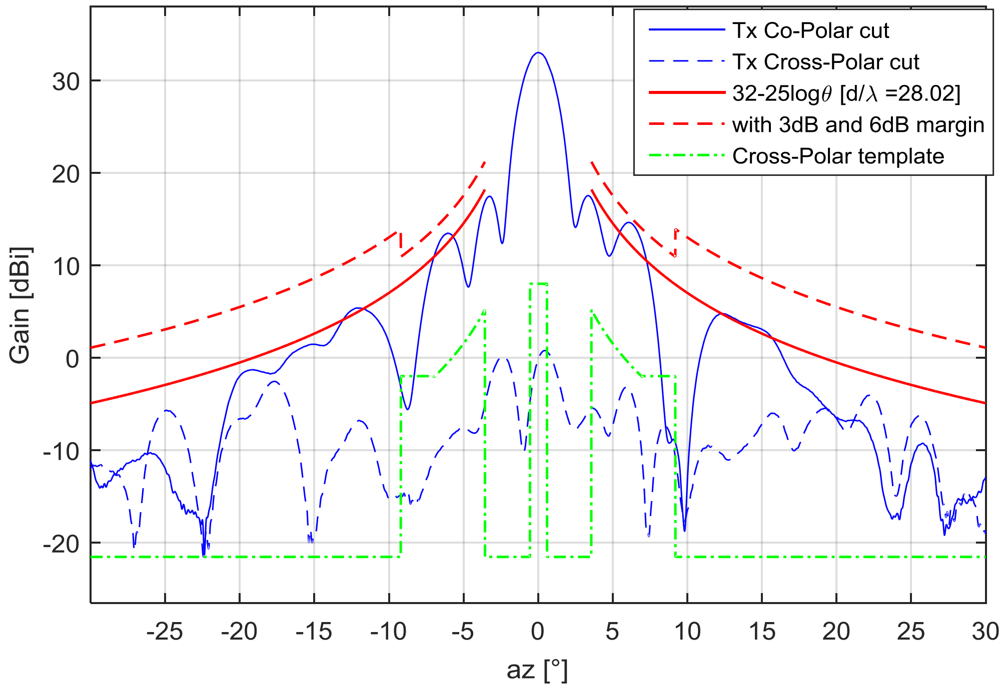


Figure 6: Tx azimuth plane cut of the commercial maritime antenna at antenna elevation 30°, frequency 14 GHz, Pol H, Radome rotation 0°

7.3.3 Verification of skew correction for non-circular apertures

FORTE allows for very accurate de-pointing estimation measurements thanks to a cross shaped sensor array with six antennas which is mounted on the antenna tower.

Figure 7 depicts a block diagram illustrating the de-pointing estimation measurement process used for dish antennas which have fixed beam patterns.

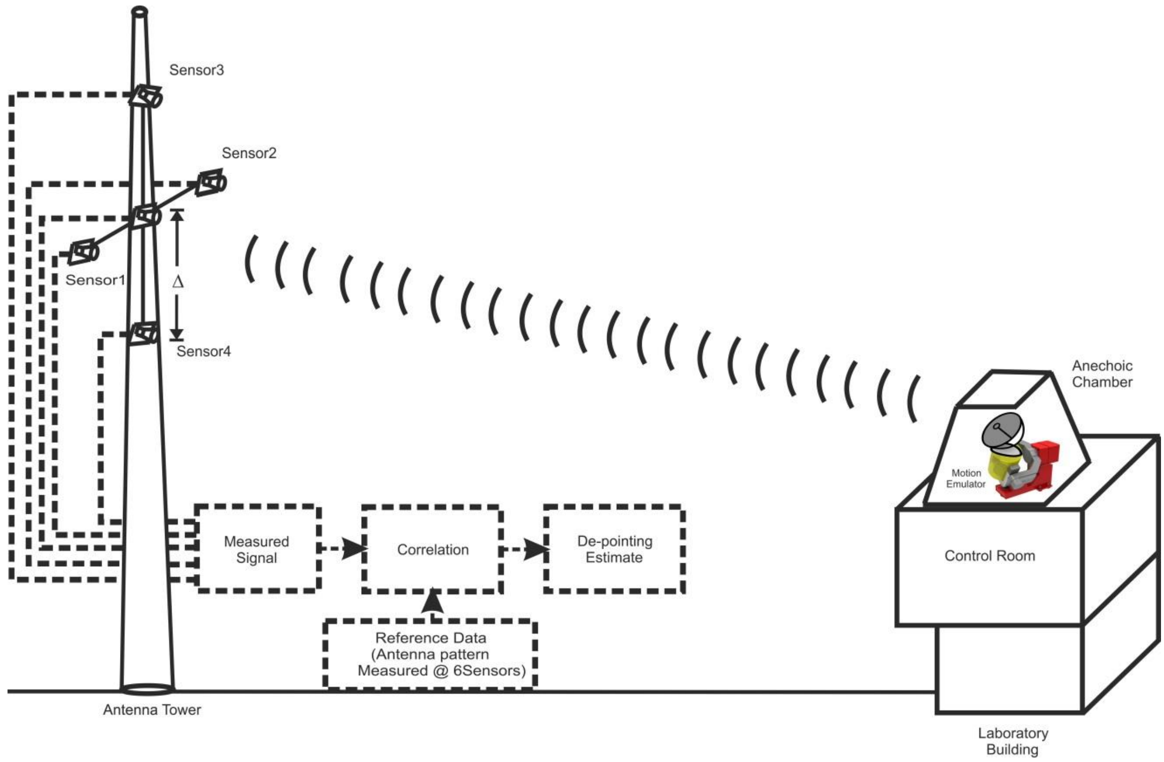


Figure 7: de-pointing measurements at the Fraunhofer Facility for Over-the-air Research and Testing FORTE

While having the SOTM terminal mounted on the motion emulator and being on the move, the signal received at the sensors on the antenna tower is correlated with the pre-measured beam pattern (Reference data). Antenna de-pointing is then estimated at the position of the maximum correlation.

In other words, the de-pointing estimation is carried out in three steps (cf. Figure 7):

1. measure the received signal from the antenna at the six sensors
2. calculate the correlation between the measured signal and the reference data
3. antenna de-pointing estimate results from the maximum of the correlation.

As an illustrative example, the de-pointing estimation of the tested commercial maritime antenna while being on the maritime Class B standard motion profile is shown in Figure 8 for azimuth and Figure 9 for elevation.

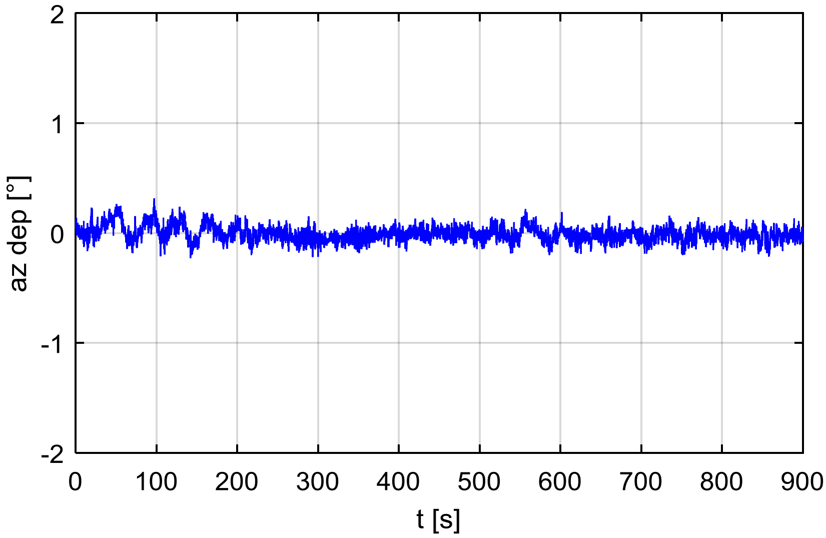


Figure 8: azimuth de-pointing of the commercial maritime antenna on the maritime Class B profile

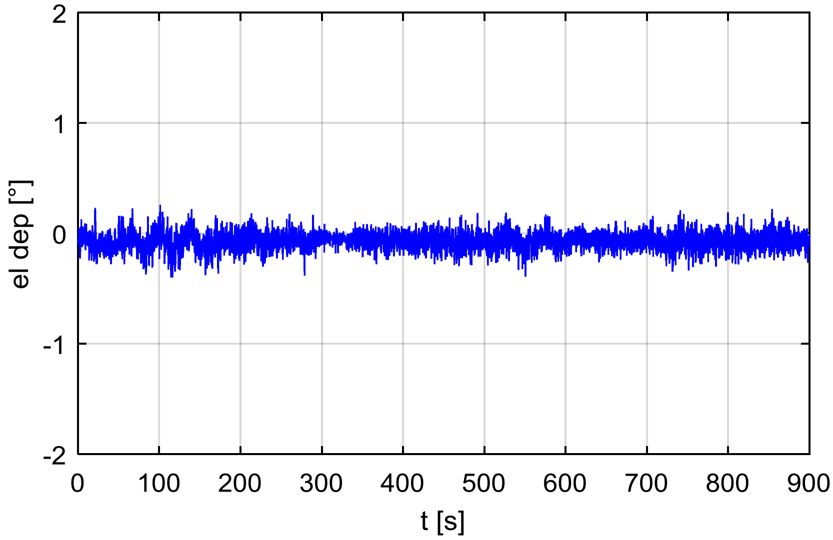


Figure 9: elevation de-pointing of the commercial maritime antenna on the maritime Class B profile

Statistical measures can be used to judge more on the pointing performance. In Figure 10 and Figure 11, the Probability Distribution Function PDF of the azimuth and elevation de-pointing are depicted, respectively.

In Figure 12, the Cumulative Density Function CDF is shown for azimuth and elevation de-pointing. From Figure 12, it can be seen that antenna de-pointing does not exceed 0.4° in any case as discussed earlier.

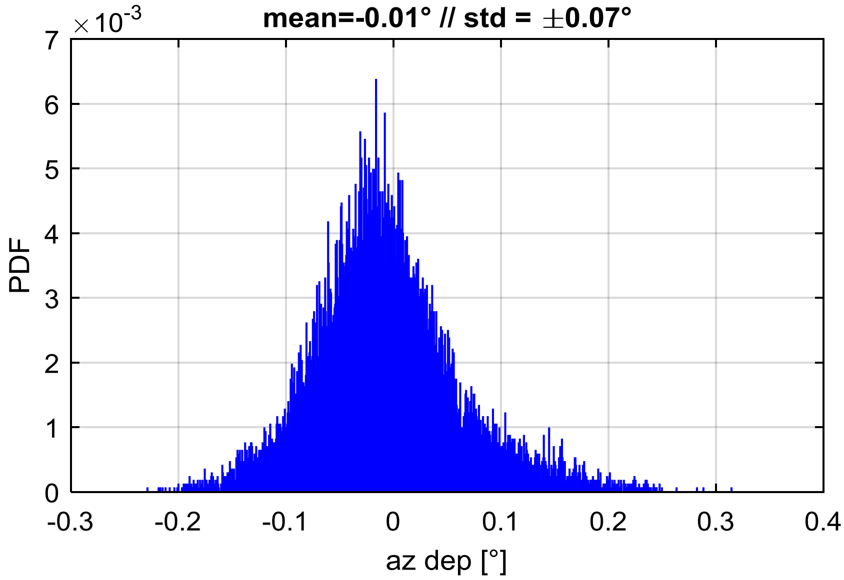


Figure 10: Probability Distribution Function PDF of azimuth de-pointing of the commercial maritime antenna on the maritime Class B profile

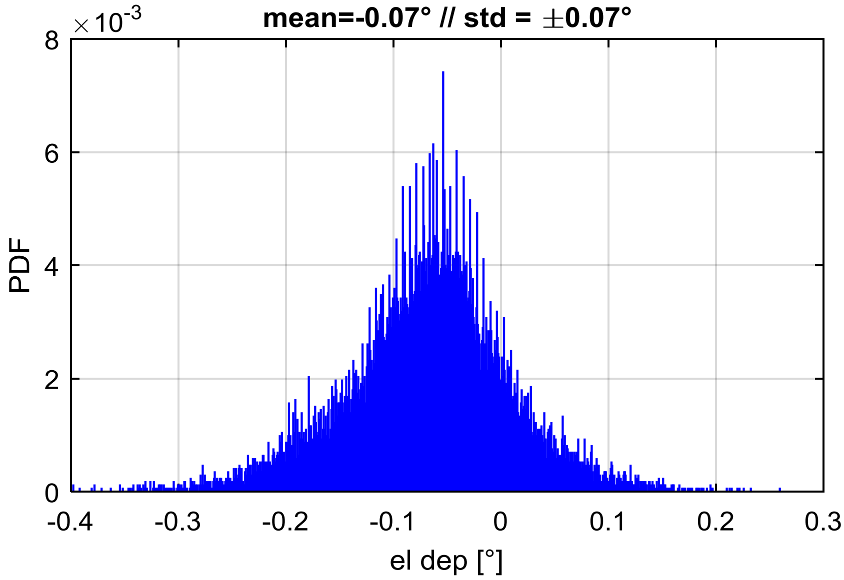


Figure 11: Probability Distribution Function PDF of elevation de-pointing of the commercial maritime antenna on the maritime Class B profile

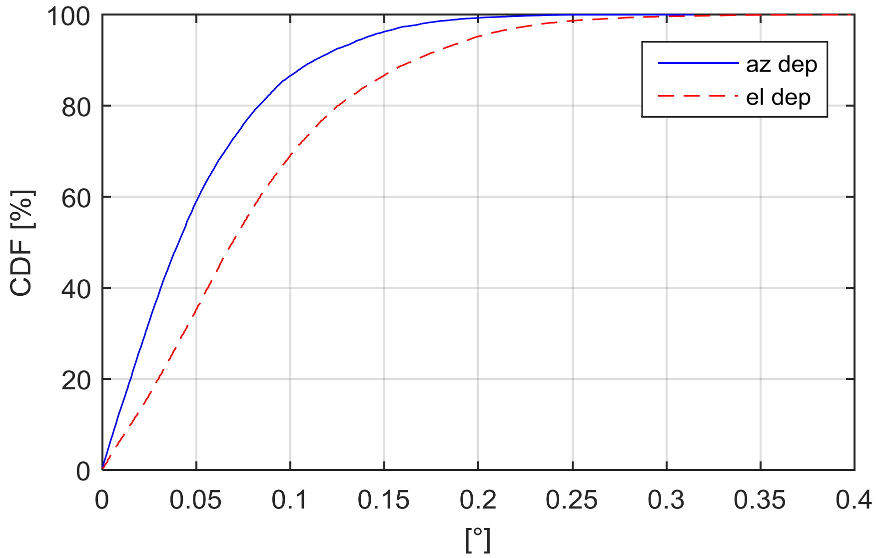


Figure 12: Cumulative Density Function CDF of de-pointing estimation of the commercial maritime antenna on the maritime Class B profile

Adjacent Satellite Interference ASI can also be measured at FORTE thanks to the ability of changing the sensor positions. As an illustrative example, the ASI caused by the antenna under test on the maritime Class B motion profile for adjacent satellites being at 1.18° is depicted in Figure 13. A judgment on the levels of the ASI is left then for the satellite operator since it depends on the scenario in which the antenna will operate.

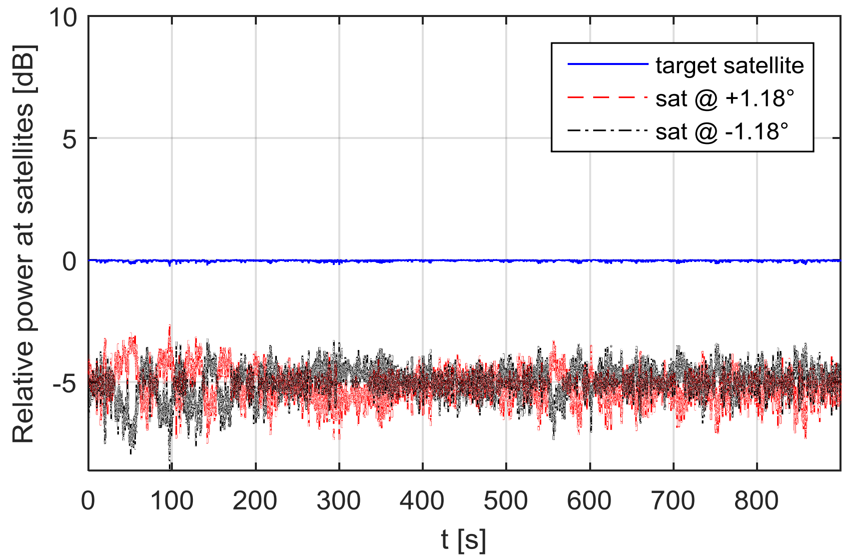


Figure 13: ASI for satellites at ±1.18° caused by the commercial maritime antenna on the maritime Class B profile

7.3.4 Verification of Transmit Inhibit/Mute Functionality

The performance of the Transmit Inhibit/Mute Functionality of the SOTM terminal can be tested at FORTE by inspecting the power levels at the tower sensors along with the de-pointing estimation results. As an illustrative example, the power levels at the tower sensors are depicted in Figure 14 for a part of the land mobile Class A standard motion profile. Figure 15 shows the corresponding azimuth de-pointing. From Figure 15, it can be seen that the antenna did not mute although the de-pointing exceeds 0.5° for more than 100 msec. This violates the mute requirements specified in the regulatory norms such as FCC and ETSI norms for SOTM terminals. However, the commercial maritime antenna under test is designed for maritime application and not suited for land mobile tracks.

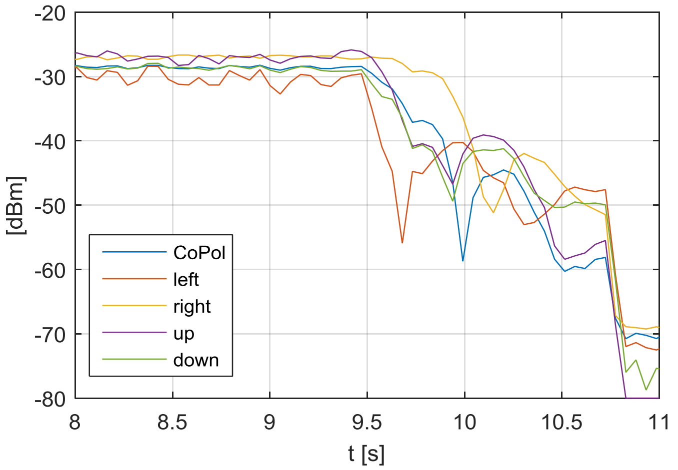


Figure 14: zoom in on the power levels at the tower sensors for the commercial maritime antenna on the land mobile Class A profile.

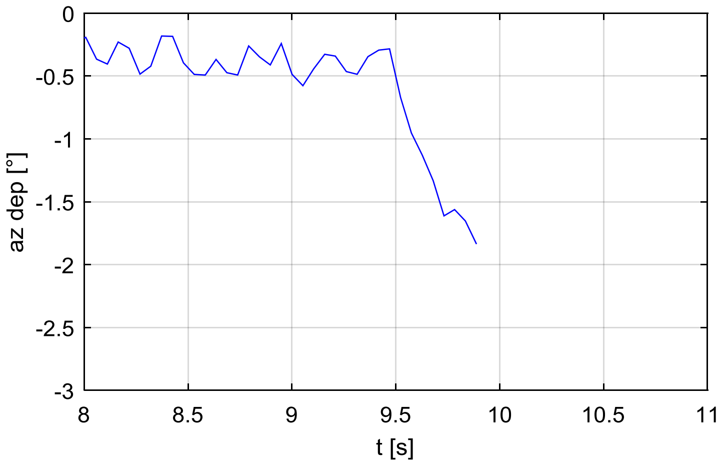


Figure 15: zoom in on the azimuth de-pointing for the commercial maritime antenna on the land mobile Class A profile.

7.3.5 Verification of data traffic (Throughput)

The performance of the modem attached to the SOTM antenna can also be tested at FORTE. Data Throughput is a direct metric to judge on the performance of the modem. Using any data traffic analysis and visualization tool such as "iperf", the data Throughput can be recorded synchronously with the replayed motion profile.
The Throughput in terms of normalized data rate can be plotted along with the de-pointing estimation results as a reference. The Complementary Cumulative Density Function CCDF of the normalized data rate is then used to judge on the modem performance. As an illustrative example, Figure 16 shows the normalized data rate and the azimuth de-pointing for the commercial maritime antenna on the maritime Class A motion profile.

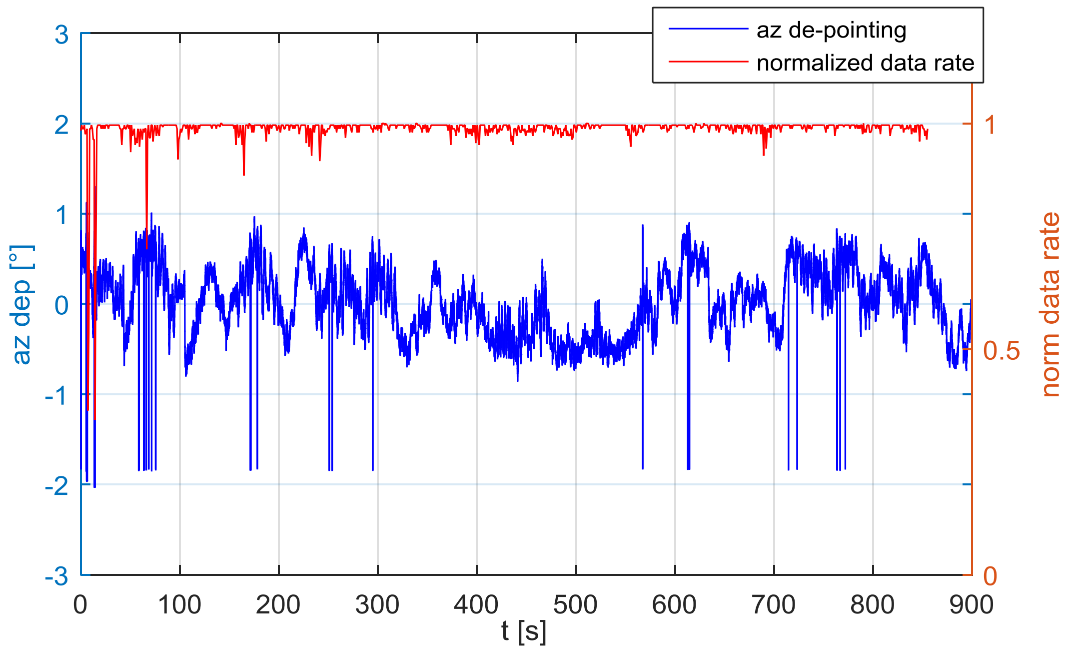


Figure 16: azimuth de-pointing and normalized data rate of a traffic test with the commercial maritime antenna on the maritime Class A motion profile

Figure 17 shows the CCDF of the normalized data rate on the maritime Class A motion profile. The data rate is above 90% of its maximum value for 99% of all cases.

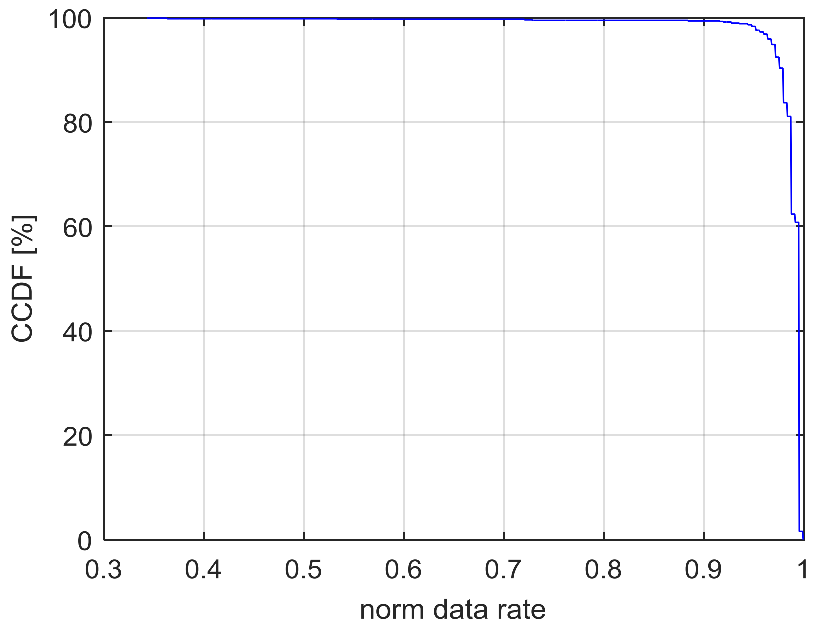


Figure 17: CCDF of normalized data rate of a traffic test with the commercial maritime antenna on the maritime Class A motion profile. The data rate is above 90% of its maximum value for 99% of all cases.

7.3.6 Presentation and summary of test results

Fraunhofer IIS analyses all collected measurements and generates a test report where the detailed results as well as comments and final conclusions are presented.

The test report includes conclusions about gain/ESD mask conformity, antenna pointing performance; transmit Inhibit/Mute performance and other performance aspects of the SOTM terminal.

As an illustrative example, Table 18 presents the summary for the azimuth plane range measurements for the commercial maritime antenna which was tested according to the EUTELSAT specifications.

The "XPD within -1 dB [dB]" represents the maximum value of XPD within the 1 dB contour of the Co-Pol pattern.

The "% over mask" column shows the percentage of the pattern which is above the regulatory EESS 502 mask defined by EUTELSAT. In the Earth Station Minimum Technical and Operational Requirements EESS 502 document, EUTELSAT specifies as a requirement that the "% over mask" should not exceed 10% in any case. The cases where the tested commercial maritime antenna does not fulfil this requirement are marked in red in Table 18.

The last six columns list the F-factors. The F-factors indicate the maximum value for pattern overshoot above the regulatory mask (the EESS mask is used in this case) for different angular ranges.

Plane	Antenna Elevation	Freq	Tx-Pol	Radome rotation	Gain [dBi]	XPD within -1 dB [dB]	% over mask	α°÷ 30°	F0.5° ÷30°	F1°÷ 30°	F1.5° ÷30°	F2°÷ 30°	F2.5° ÷30°
Azimuth	30°	14GHz	H-pol	0°	32.99	36.69	13	2.46	2.46	2.46	2.46	2.46	2.46
				90°	32.99	40.14	15.52	2.62	2.62	2.62	2.62	2.62	2.62
				150°	32.99	40.61	17.94	3.57	3.57	3.57	3.57	3.57	3.57
				270°	32.99	36.53	11.79	2.48	2.48	2.48	2.48	2.48	2.48
				OFF	32.99	33.74	0	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2
			V-pol	0°	32.99	41.47	3.93	2.5	2.5	2.5	2.5	2.5	2.5
				90°	32.99	38.39	4.05	2.79	2.79	2.79	2.79	2.79	2.79
				150°	32.99	52.23	3.65	2.14	2.14	2.14	2.14	2.14	2.14
				270°	32.99	51.71	4.58	2.87	2.87	2.87	2.87	2.87	2.87
				OFF	32.99	40.64	1.15	1.14	1.28	1.28	1.28	1.28	1.28
		14.25GHz	H-pol	0°	33.11	36.22	4.12	2.97	2.97	2.97	2.97	2.97	2.97
				90°	33.11	44.77	3.72	2.48	2.48	2.48	2.48	2.48	2.48
				150°	33.11	32.99	3.72	2.46	2.46	2.46	2.46	2.46	2.46
				270°	33.11	35.48	4.18	2.98	2.98	2.98	2.98	2.98	2.98
				OFF	33.11	33.69	0	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7
			V-pol	0°	33.11	51.69	9.18	3.49	3.49	3.49	3.49	3.49	3.49
				90°	33.11	51.52	8.88	4.1	4.1	4.1	4.1	4.1	4.1
				150°	33.11	51.78	9.52	3.03	3.03	3.03	3.03	3.03	3.03
				270°	33.11	51.33	13.17	3.86	3.86	3.86	3.86	3.86	3.86
				OFF	33.11	50.6	0.12	0.14	0.25	0.25	0.25	0.25	0.25
		14.5GHz	H-pol	0°	29.25	33.68	0	-1.8	-1.8	-1.8	-1.8	-1.8	-1.8
				90°	29.25	29.8	0	-2.5	-2.5	-2.5	-2.5	-2.5	-2.5
				150°	29.25	29.93	0	-2.2	-2.2	-2.2	-2.2	-2.2	-2.2
				270°	29.25	33.68	0	-2	-2	-2	-2	-2	-2
			V-pol	0°	29.25	49.99	0	-2.5	-2.5	-2.5	-2.5	-2.5	-2.5
				90°	29.25	48.56	0	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8
				150°	29.25	48.98	0	-2.4	-2.4	-2.4	-2.4	-2.4	-2.4
				270°	29.25	48.57	0	-2.4	-2.4	-2.4	-2.4	-2.4	-2.4
	0°	14GHz	H-pol	0°	32.99	42.87	15.55	5.78	5.78	5.78	5.78	5.78	5.78
			V-pol	0°	32.99	36.27	13.3	3.64	3.64	3.64	3.64	3.64	3.64
		14.25GHz	H-pol	0°	33.11	41.29	7.85	3.63	3.63	3.63	3.63	3.63	3.63
			V-pol	0°	33.11	36.09	14.11	5.72	5.72	5.72	5.72	5.72	5.72
		14.5GHz	H-pol	0°	29.25	46.57	0	-0.9	-0.9	-0.9	-0.9	-0.9	-0.9
			H-pol	0°	29.25	47.4	0	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7

Table 18: summary of Azimuth Plane Range Measurements for the commercial maritime antenna

Table 19 presents the summary for the pointing performance measurements for the tested commercial maritime antenna. Information about different motion tracks on which the antenna has been tested at FORTE is listed. For each track, the maximum angular rate, the maximum de-pointing, the worst measured XPD, the required EIRP reduction at the worst case de-pointing and information about the Adjacent Satellite Interference ASI worst levels are summarized in Table 19.

Test #	Motion track	Max Ang Rate [°/s]	Pol [Tx/ Rx]	Mute Fct.	Max. abs. az de-pointing in deg	Max. az de-pointing [Q99] in deg	Max. az de-pointing before 1st mute in deg	Worst XPD [dB]	EIRP reduction at worst de-pointing [dB]	ASI @ 1.18° [worst/best] in dB	ASI @ 2.36° [worst/best] in dB	ASI @ 3.53° [worst/best] in dB
1	Stationary	0	H/V	OFF	0.26	0.11	-	21.97	0.55	[2.7/7.7]	[20.8/31]	[18.4/23]
2	MaritimeB	4.92	H/V	OFF	0.31	0.2	-	20.52	0.94	[2.3/8.2]	[20/31]	[18/23]
3	MaritimeB	4.94	H/V	ON	0.31	0.19	-	20.34	0.94	[2.4/8.4]	[20/31]	[18.3/23]
4	Land-mobileB	26.48	H/V	ON	0.64	0.25	-	3.5	3.3	[-0.4/13]	[11/31]	[17/27]
5	Sine (in-phase)	54.37	H/V	ON	0.72	0.57	0.72	2.23	3.85	[-1/15]	[9/31]	[17/27]
6	Land-mobileB	26.51	H/V	OFF	0.75	0.27	-	15.4	4.05	[-1.4/15]	[8/31]	[17/27]
7	Land-mobileA	70.6	H/V	ON	1.88	1.52	1.8	-3	9.95	[-14/26]	[-14/31]	[-4/28]
8	MaritimeA	26.5	H/V	OFF	2.03	0.29	-	13.31	10.57	[-18.5/23.9]	[-20/31]	[-12/28]
9	MaritimeA	26.47	H/V	ON	2.03	0.31	-	12.16	10.57	[-18.5/24]	[-20/31]	[-12/28]
10	Land-mobileA	70.5	H/V	OFF	2.03	1.64	-	-21.1	10.57	[-18.7/27]	[-21/31]	[-12/28]
11	Sine (in-phase)	54.37	H/V	OFF	2.03	1.9	-	-22	10.57	[-18/27]	[-20/31]	[-12/28]

Table 19: pointing performance results for the commercial maritime antenna sorted according to worst de-pointing. The worst cases are marked in red.

The conclusions drawn in the test report (e.g. Table 18 and Table 19) enable the satellite operators to decide if the performance of the terminal is acceptable. They also enable the manufacturers to better understand their products and know how they can be improved.

7.4 New Capabilities and supporting data

The outcomes of the consultation plan implemented in Task 3 of this project revealed that some capabilities and supporting data are still missing to achieve complete standard testing and type approval conditions for SOTM terminals. In this Section, the major new capabilities and supporting data are discussed. The associated tasks including their duration and costs are highlighted.

7.4.1 Motion standards for the aeronautical and train environments

In the context of the ESA ARTES 5.1 project titled "Characterization of the Mobile Tracking Needs (CCN2) // contract 4000103870/11/NL/NR", standard motion profiles were defined for the land mobile and the maritime environments. In the interviews carried during the processing of Task 3 of this study, positive feedback has been received from the major satellite operators, service providers, VARs, and manufacturers w.r.t. the standard motion profiles. Moreover, solid requests to define standard motion profiles for the aeronautical and the high speed train market segments were received.

Associated tasks

Measurement data for the aeronautical and high speed train environments must be collected as a first step. Performing measurement campaigns or purchasing data from a relevant authority are envisaged for this task. Different partners where contacted and responses including possibilities and costs were received:

1. **The German Aerospace Agency DLR:** 10 hours of motion data for a Falcon20E jet measured during research activities with different altitudes and speeds were purchased. 14 hours of motion data for a local German train and a local Italian train were also purchased.
2. **Technische Universität Hamburg TUHH / IMST GmbH:** The discussion might lead to the opportunity of performing measurements on jets owned by DLR.

On the other hand, measurements in the German high speed trains (ICE) are planned by Fraunhofer IIS. Contacts have been initiated to explore the different measurement opportunities.
After collecting the measurement data, statistical analysis is to be performed in a second step. The statistical analysis leads to the definition

of standard motion profiles. The profiles are then presented to the SOTM market representatives, e.g. to the GVF-MRA working group which includes many satellite operators and terminal manufacturers. The feedback collected is then considered to refine and finalize the standard motion profiles.

Associated costs

Performing measurements on an airplane is very expensive due to the nature of the aeronautical environment and the strict safety measures implemented for jet flights. It is evident that purchasing previously measured data is cheaper than renting a carrier to perform private measurements. Fraunhofer IIS contacts research institutes and non-profitable institutions in order to reduce the costs.

1. **The German Aerospace Agency DLR:** The data were purchased with low price under the restriction that it is to be used internally for research purposes and not commercially to perform measurements for manufacturers and operators, otherwise additional costs are to be added.
2. **Technische Universität Hamburg TUHH / IMST GmbH:** The possibilities and costs are still under discussion.

For an own measurement campaign performed in the German ICE train network, an estimated cost of 25.000 EUR will be sufficient.
In order to cover the expenses and to perform the data analysis, a project framework is required. Fraunhofer IIS is currently exploring further possible partners especially in the aeronautical field as it is most difficult to acquire data for air jets. Further discussions with the German delegate w.r.t. funding through ARTES 5.1 are ongoing. The earliest possible support letter for a CCN in the ARTES 5.1 is in the beginning of 2017. In order to perform the underlying actions, an extension of the current CCN (CCN3) will be possible in 2017.

Associated time plan

Based on experience from the land mobile and maritime measurements, a period of up to one year is estimated to complete the task of defining standard motion profiles for the aeronautical and train environments. It highly depends on how fast the acquisition of the measurement data can be achieved

7.4.2 Standardization of shadowing profiles

An additional step towards achieving a standard SOTM testing environment is to define standard fading profiles. The land mobile satellite LMS channel associated to a mobile environment is an important factor which is affecting the performance of the SOTM terminal. A terminal operating in an urban environment is facing shadowing conditions which are different than those in a rural area. On the other hand, the channel in a maritime environment is different than the channel in a land mobile or an aeronautical environment. A deliberate definition of shadowing profiles has not been considered so far in the literature.

In order to define standard shadowing profiles, two main aspects need to be addressed:

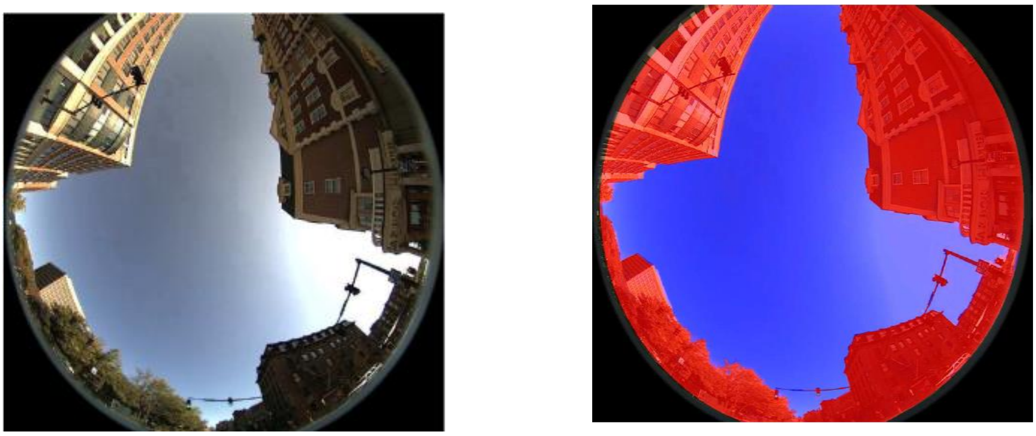
1. A technique to measure the shadowing channel is to be defined. In other words, a relationship between the environmental blocks and the RF signal needs to be described.

2. A model of standard shadowing profiles based on the environment type needs to be adopted. A SOTM terminal which is designed to operate in a maritime environment needs to be tested under the effect of the fading profiles defined for the maritime environment and not for the land mobile environment.

Associated tasks

Fraunhofer IIS developed an image based approach to determine the fading channel [5]. This approach has the advantage that the fading channel can be estimated for different satellite positions without performing extra measurements. On the other hand, the RF based approach needs extra hardware or measurement repetitions if different satellite positions need to be considered.

In the proposed image based approach, the channel fading is characterized by a statistical based approach to distinguish between good (Line Of Sight LOS) and bad (Light shadowing and Non-LOS) states. A hemispheric image of the environment is obtained from a fisheye camera pointing towards the sky. Such an image is depicted in Figure 18(a). A categorization algorithm divides the hemispheric image into the region sky, where a satellite would be visible and the region obstruction, where it would be shadowed by an object. An example of this categorization is given in Figure 18(b), where sky is depicted in blue and obstruction in red.



(a) An exemplary hemispheric image

(b) An overlay consisting of the original and the binary categorization into sky and obstruction

Figure 18: the images show the original hemispheric image and the result of the image categorization

In a second step, the conversion from the processed fisheye images to rectangular binary image in landscape panoramic form is performed, as shown in Figure 19. The reception state can be extracted directly from this image, where white represents good and black bad state, respectively. By simple geometric considerations, knowing the time and location information of the vehicle, the reception states for any possible satellite position can be extracted using the panoramic images.

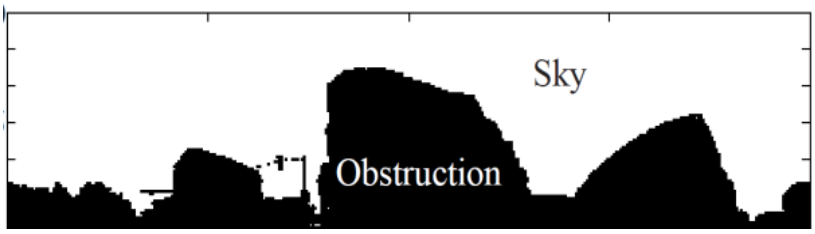


Figure 19: the converted panoramic binary images are of size 90×360 pixels, where the resolution is one degree in elevation and in azimuth. White represents the receptions state good and black bad, respectively

The channel emulation at FORTE can be performed based on the sequence of reception states derived from the images. An extensive validation of the method can be found in [5], where simultaneously recorded Radio Frequency (RF) signal levels as a reference were considered. The results demonstrate that the image-based approach is a reliable method for availability prediction for arbitrary satellite positions.

Figure 20 shows an exemplary fading sequence which can be emulated at FORTE. The sequence is for a satellite at 25° in elevation and 10° in azimuth for two different environment types: suburban and highway.

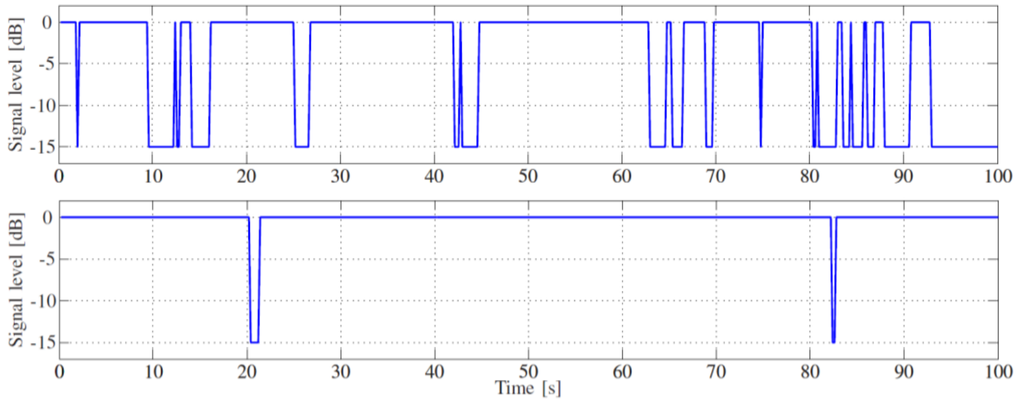


Figure 20: examples of fading profiles as power levels over time for different environments suburban and highway for a satellite positioned at 25° elevation and 10° azimuth

Weather conditions can be added to the emulation process e.g. rain fades where the whole time sequence will be shifted down by the rain fade factor as shown in Figure 21.

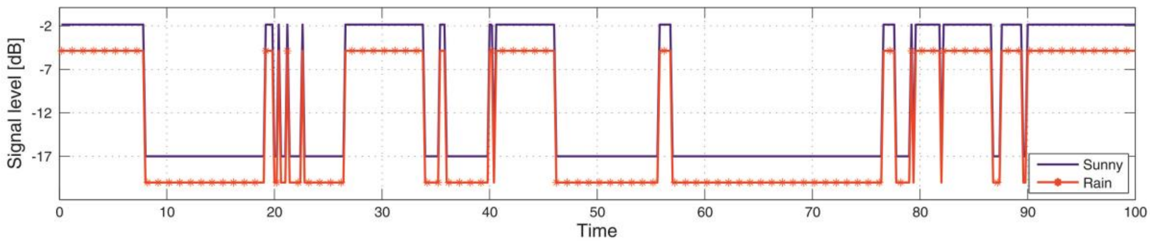


Figure 21: Exemplary fading profiles as power levels over time in urban environment for a satellite positioned at 25° elevation and 10° azimuth. The received satellite signal characteristic for sunny weather is plotted in violet and for rainy weather in red, respectively. The vertical axis represents the signal level in dB where 0 dB corresponds to LOS

Using the image based approach a statistical model for generating the shadowing profiles for the different environment types will be investigated. The shadowing profiles will be used synchronously with the motion profiles to test the SOTM terminal.

The tasks associated can be summarized according to the environment as follows:

1. Land mobile: images were collected for most of the measurements in the context of the ESA ARTES 5.1 project "Characterization of the

Mobile Tracking Needs". The definition of standard shadowing profiles based on statistical models will be investigated for the different sub environments, e.g. urban, rural, and suburban, etc.

2. Maritime and aeronautical: the channel is almost all the time Line of Sight LOS. The body of the ship mast or the airplane might shadow the signal in some instances. A simple model which is able to characterize such a nature will be investigated. Measurements with the fish-eye camera will be performed in parallel to what is described in Section 7.4.1.
3. High Speed Trains: The shadowing conditions mainly include tunnels and trees. Relevant standard shadowing profiles based on statistical models will be defined.

Associated costs

The data analysis and measurements, if required, need to be defined in the context of a project work. The funding opportunities and availabilities are being explored by Fraunhofer IIS.

Associated time plan

Based on experience Fraunhofer IIS collected while defining the standard motion profiles, a period of up to one year (in parallel to the tasks in Section 7.4.1) needs to be considered for performing image based channel measurements and to define standard fading profiles for the different environments.

7.4.3 Pointing performance evaluation

The design of SOTM terminals is moving in the direction of implementing phased arrays instead of dish antennas. Phased arrays have the advantages of being small and compact. However, the characteristic of having non-fixed beam pattern which changes depending on the steering direction makes it tough for the satellite operators to test the performance of SOTM terminals which incorporate phased arrays. The authors are not aware of any facility worldwide which has the ability to measure the antenna patterns of a phased array. This makes it difficult to evaluate the terminals pointing performance.

A SOTM terminal can still be tested in a free field using operational satellites; however, this method of testing is very expensive and does not insure repeatability. Moreover, the exact antenna de-pointing estimation is not possible in a free field test. Only other measures such as Adjacent Satellite Interference ASI can be used.

The difficulty in measuring the antenna patterns of phased arrays and therefore the difficulty in evaluating the pointing performance represents a huge problem to the different parts of the SOTM market chain. Satellite operators cannot judge the performance of the SOTM terminal and the terminal producers cannot enhance their products since there is no defined way to test them.

Fraunhofer IIS proposes a solution based on the extension of FORTE. Two possibilities are proposed:

1. The Adjacent Satellite Interference ASI can be measured and used as a metric to judge on the pointing performance of the phased array.

2. The main beam of the phased array radiation pattern can be measured online while the terminal is On-The-Move by increasing the number of sensors mounted on the antenna tower at FORTE.

Associated tasks

The relevant associated tasks are as follows:

1. If ASI is to be measured, sensors at the positions of the adjacent satellites can be mounted on the antenna tower at FORTE (cf. Figure 7) to measure the signal levels received at the adjacent satellites (ASI). Changing the structure on which the sensor array at FORTE is mounted can enable moving the outer sensors to be located at the position of the adjacent satellites.
2. If antenna de-pointing is to be estimated. Extra sensors need to be mounted on the antenna tower compared to the current status of FORTE which includes only 5 sensors (c.f. Figure 7). A new structure to hold the new sensors need to be manufactured. More hardware including antennas, power detectors, measurement cards, etc. need to be purchased. A calibration process follows in order to correctly integrate the new sensors in the existing measurement

chain. The transfer function of each sensor will be measured and included in the measurement algorithms. An illustrative drawing showing the proposed extension of FORTE including mounting a new mesh of sensors is depicted in Figure 22.

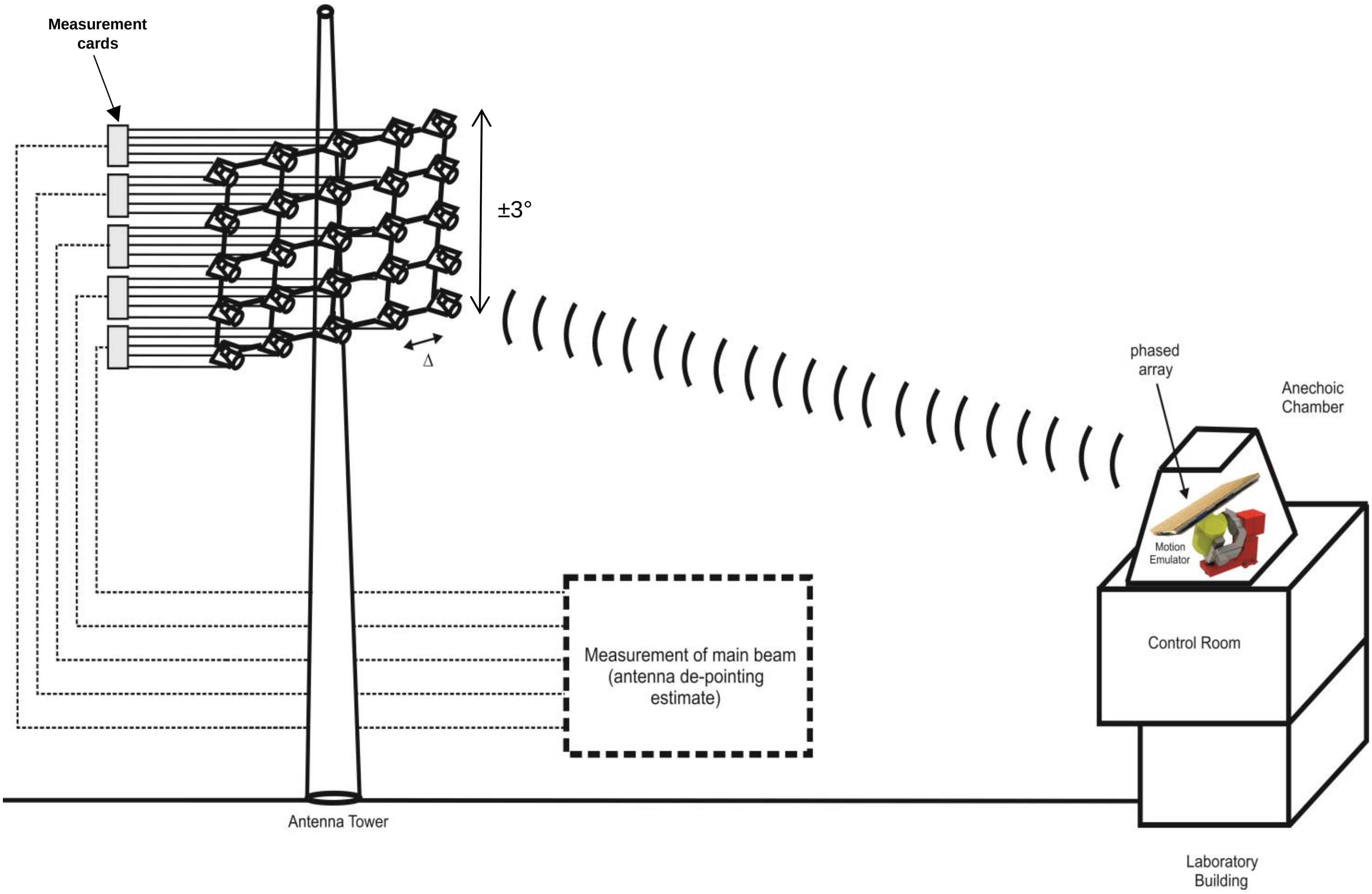


Figure 22: Extension of the de-pointing Measurement system at the Fraunhofer Facility for Over-the-air Research and Testing FORTE to enable measuring de-pointing of phased arrays and antennas with dynamic beam pattern

The number of sensor and their positions, i.e. the resolution of the sensor grid (Δ), depends on the 3dB beam width of the antenna pattern.
Based on the results of a preliminary simulation, Figure 23 depicts the relationship between the antenna 3dB beam width and the number of sensors required for perfect recovery of the radiation main beam and first side lobes. Figure 24 shows the relationship between the 3dB beam width and the separation between the sensors.

Figure 23 together with Figure 24 define how an extension of FORTE is to be implemented.

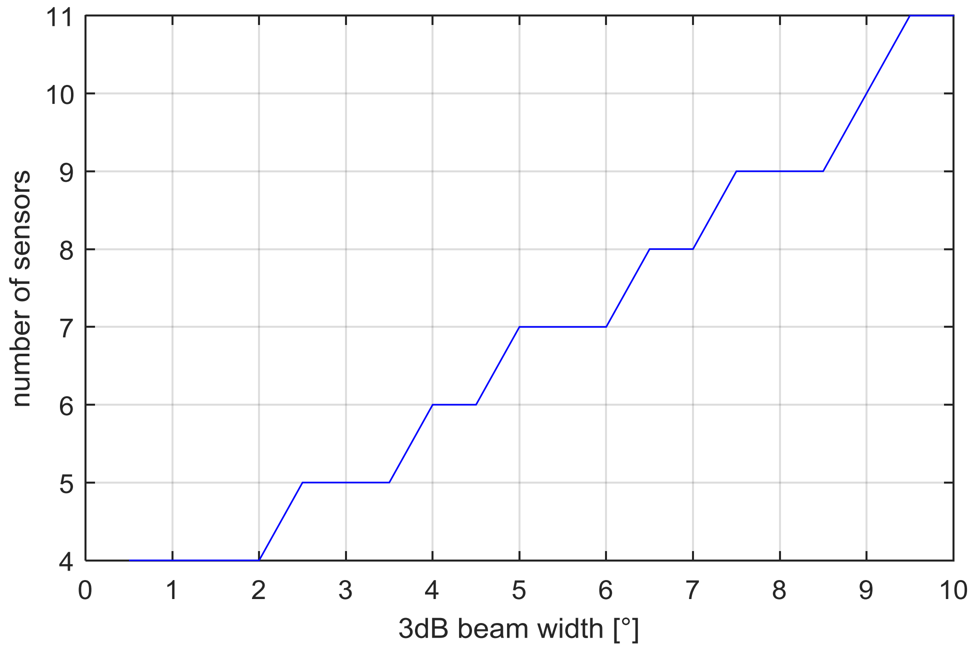


Figure 23: The number of sensors (per axis) required for the reconstruction of the main beam and the first side lobes w.r.t. the 3dB beam width of the antenna

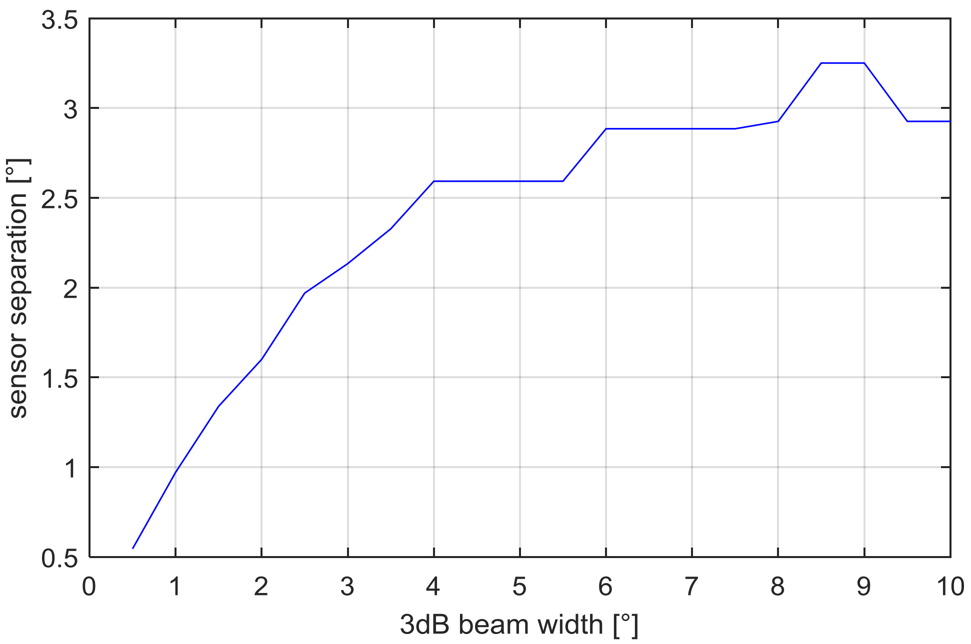


Figure 24: The sensor separation required for the reconstruction of the main beam and the first side lobes w.r.t. the 3dB beam width of the antenna

Associated costs

A complete sensor (including an antenna and a power detector) costs about 10.000 EUR.

Associated time plan

For the procurement and mounting of the proposed sensor grid, a period of 12 months is to be considered.

7.5 Standardised technical terms GVF-106

GVF-106 is a document in development outside the scope of the ESA study.
An important component of the GVF/ Fraunhofer study conducted for ESA has been the interaction between the GVF/FHG team and technical experts within the manufacturing and satellite service provider market segments. The satellite service providers are often called upon to perform communications link analysis to determine link margins and the reliability of the links provided to their customers and value added resellers. A key component of this analysis encompasses the performance provided by the equipment used in the customer's ground terminals. Decisions regarding the suitability of individual components, sub-systems and complete terminals are often reached on the basis of advertised performance found in manufacturer's product literature and technical specification data sheets. This situation is of even more importance if a satellite service operator is considering solutions which may not use formally type approved equipment. The lack of consistency in the way in which product performance is described in the market place has introduced serious problems for actors in the satellite service provider sector. The following two examples have been included to illustrate this point.

Antenna Gain: Manufacturers product data sheets are not consistent in the way in which antenna gain is advertised. In some cases gain is defined at mid band frequencies whereas in other instances typical gain values are described without mentioning that the product may have "drop outs" where the gain falls well below the average value across a given band. In other cases antenna gain may be references to the antenna input flange and exclude losses associated with necessary components

(OMT's, filters, polarizers etc.) which would normally be included in the transmission path between the radio, LNB/LNA and antenna input flange.

The interpretation of antenna gain as defined in a manufacturers specification sheet can also be complicated by the type of antenna used in a SOTM terminal. In the case of reflector antennas which have been traditionally been deployed in the SOTM market, the antenna gain remains constant at any defined frequency as the antenna is scanned over the operational range of "look angles" required to maintain the link. Advances in technology have resulted in the introduction of new designs comprising phased arrays and similar solutions. The benefits of these solutions are:

- they by and large have no "moving parts".
- they can track at much higher speeds and are not limited by the physical inertia imposed by the mechanical solutions.
- they are generally lighter in weight.
- they are often low profile making them ideal solutions for high speed and airborne applications.

On the negative side, the gain and antenna pattern coverage characteristic of phased array solutions are not stable. In general terms the antenna gain may decrease from its peak value by the cosine of the angle through which the pattern is scanned. Additionally the sidelobe envelope will degrade with the development of coma lobes as the pattern is scanned from the peak value. Both conditions can quickly combine to drive the performance of a phased array solution in to non-compliance condition with respect to satellite service provider's specification requirements. It thus becomes incumbent on a manufacturer to clearly state the scan angle limits for which their phased array solutions comply with a specification requirement.

Terminal Configuration: The level at which a terminal has been qualified requires better definition. This is of particular significance for the expanding airborne SOTM market. It has been reported that terminal equipment may have selected based on the declaration that a particular product has been type approved at the "terminal level". When the terminal is integrated in to an airframe, a radome is required to protect the terminal from the aerodynamic loads. The impact of radomes on the performance of a type approved antenna can be significant. It has been reported (and seen in this study) that radomes in many instances will degrade the performance of a qualified terminal to below acceptable levels. In other instances, satellite operators have reported cases where and equipment integrator may utilize a type approved terminal and modify the support structure with additional hardware that degrades the performance of the type approved terminal configuration. Examples here include hardware adapted to satellite news gathering information (coms-on-the-pause and SOTM terminals).

The negative consequences of loosely specified products, or modified products for a particular application is unintended and often results from a manufacturer not knowing the details of the environment in which a type-approved sub-system may be deployed. To ameliorate this situation, a number of the satellite service providers approached the GVF to identify speciation items commonly used by the industry and to recommend performance definitions which would remove ambiguities in the way in which particular terminology was to be interpreted. A project was started by the GVF to address these concerns and is on-going. The GVF has released a draft of a new document GVF-106 titled, “Glossary of Standardised Technical Terms”. This document will continue to be revised through the normal GVF review process in order to capture and incorporate all of the concerns expressed by the satellite service provider and manufacturing market segments.

The following pages contain four tables which identify items that be specified for SOTM and traditional VSAT terminals. The first table covers the terminology relevant to the electrical / RF performance of terminal. The second and third tables address the system and RF electronics level specification items which tend to be independent from the radiating antenna components. The final table captures the mechanical / tracking accuracy parameters for a terminal including the time to mute an uplink signal if the terminal mis-points by allowable limits.

The purpose for identifying each of the terms contained in the tables is to establish a listing of the items which should be included on manufacturer’s specification sheets and then to provide definitions as to how the manufacturer’s specifications shall be defined and interpreted. The listing will not include actual values as these are dependent on the requirements of national regulators and individual satellite service providers.

A sub-group of satellite operators has been established through the GVF to develop “strong” recommendations for minimum performance requirements. This group comprises representatives from Inmarsat, Intelsat, Eutelsat, AsiaSat and SES. The results of their activities are currently under an NDA but will be incorporated in to the ESA study.

Table 7.5-1 Antenna Performance Terminology				
Phrase	**Term**	**Definition**	**Required parameters**	**Comments**
Gain in dBi	**Gtx (dBi)** **Grx (dBi)**	Ratio of max power solid-angle density radiated by the antenna (at boresight) compared to that of an isotropic antenna radiating equal power solid-angle density.	• Clearly identifies reference plane for stated gain (e.g. horn, combiner, polarizer). • Clearly includes radome losses if radome is used. • Includes feed and polarizer losses. • In the case of phased arrays, the minimum gain shall be stated over the operational range of frequencies and scan angles.	• Must include a defined frequency band(s) Ref: Freeman, Ref Manual for Telecom Engineering, p. 1275 Minimum gain across operational band unless stated for specific frequencies • Default at feed port unless stated For arrays, Gain at zero scan angle or stated as a function of scan angle or max/min
Directivity	dB	Ratio of max power solid-angle density radiated by the antenna (at boresight) compared to the average power solid-angle density over the sphere.	Does not include feed and polariser losses.	• Directivity is determined from the antenna pattern characteristics and does not include other losses due surface imperfections of a reflector or feed spill-over.

Table 7.5-1 (continued) Antenna Performance Terminology				
Phrase	**Term**	**Definition**	**Required parameters**	**Comments**
Cross-Pol Discrimination, Polarization Discrimination, XPD	**XPD (dB)**	The ratio of gain in a given polarization to gain in the opposite polarization, both at a given angle theta from the main beam. Theta = 0 implies on-axis; otherwise implies off-axis.	• XPD to be defined within the pointing error for the antenna and to include the effects of satellite ephemera. • Worst case XPD also to be stated for operational environmental extremes to which the antenna is exposed. • The XPD "gain envelope as a function of angle" shall be satisfied to regulatory limits much in the same way as the co-pol gain masks are established.	• From the satellite service provider perspective, poor uplink XPD performance degrades the frequency reuse capabilities of the service providers satellite. • The effects of poor XPD on an uplink may be mitigated by limiting the uplink EIRP from a terminal such that off-axis EIRP densities do not exceed limits established for fully compliant terminals. • Poor terminal XPD in the receive band has a primary impact on the QoS for a particular customer operating the terminal. There are no adverse effects to other customers resulting for selecting a terminal with degraded XPD performance.
Cross-Pol Isolation, Polarization Isolation	CPI (dB)	The ratio of gain in a given polarization on the axis of the main beam, to gain in the opposite polarization at a given angle theta off-axis from the main beam.		
Azimuth or elevation lock-down shift	(degrees)	Maximum amount that beam deflects in azimuth or elevation respectively, as its locking fasteners are tightened after antenna pointing adjustments are complete.	Fixed, non-motorized antennas	• Not applicable to SOTM terminals

Table 7.5-1 (continued) Antenna Performance Terminology				
Phrase	**Term**	**Definition**	**Required parameters**	**Comments**
Fine-adjustment hysteresis in az or el	(degrees)		Fixed, non-motorized antennas	Not a concern for SOTM terminals or phased arrays
3/10dB beamwidth	(degrees)	Width of main antenna beam at the specified level down from the antenna peak of beam		Frequency dependant, so should note freq or if a min/max value
Waveguide input size		Size of the waveguide aperture		Diameter and flange detail
Operational Windload	**V-operational (mph / kmph)**	Antenna peak of beam can move by an allowable amount, but must return to nominal pointing position. Must meet other performance requirements stated at this wind load unless specific degradation is stated.	Wind speed and angular movement	Must meet other performance requirements stated.
Functional/operational survival	(mph)	No mechanical deformation of antenna, and can be repointed	Wind speed	
Survival	V-survival (mph / kmph))	Mechanical deformation meaning the antenna is no longer operational (cannot become windblown debris)	Wind speed	Limiting maximum wind speed at which antenna will survive but may require adjustment to compensate for movement following exposure to high wind speed event. Requires that all antenna components remain attached to parent structure and be undamaged.

Table 7.5-1 (continued) Antenna Performance Terminology				
Phrase	**Term**	**Definition**	**Required parameters**	**Comments**
System Noise Temperature	**Ts (degK)**	Ts=Ta +Tr = Sum of noise temperature of antenna and receiver.		
Noise Figure	NF/N_lnb	Maximum LNB noise figure across the stated Rx band		
Surface Accuracy, RMS	(ins or mm)	RMS of the antenna surface, referenced to the nominal focal length		Various methods can be used, each giving a different result e.g. Best fit, Centre weighted, Absolute
Sidelobe mask	**(gain dB Vs angle)**	Production antenna patterns sit below the stated mask	Sidelobe performance shall be determined from antenna pattern measurements over the angular ranges and frequency bands of interest.	Sidelobe masks are established prevent interference to adjacent satellite services. The ITU is the primary body for establishing requirements but more stringent requirements may be imposed by regional regulators or satellite service providers.
Input match / VSWR / Return Loss	**dB**		Reference plane (e.g. horn, combiner, polarizer) The reference value shall include the effects of interactions between a radome if used.	Worst case in the band
Insertion Loss	Lant (dB)	Absorptive losses typically of feed and polarizer. Radome loss may also be stated.	Reference plane (e.g. horn, combiner, polarizer) Includes radome or not	Losses of various up-stream transmission line components must be combined and subtracted from antenna gain at input flange unless included in published specification performance.
Port-to-Port Isolation	dB	This specification defines the “cross talk” between the Tx and Rx ports in a VSAT or SOTM terminal.		

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Table 7.5-1 (continued) Antenna Performance Terminology

Phrase	Term	Definition	Required parameters	Comments
Axial ratio (AR)	**AR**	For circular polarization, the ratio of the eccentricity. See XPD		Worst case within operating frequencies
Size	**D**	Antenna reflector dimensions or equivalent circular aperture size presented by the antenna towards the satellite		
Adjacent Satellite Interference rejection	(dB)	Level down from bore site of signal seen by neighbouring satellite	including pointing accuracy, squint and topo-centric angle	
Beam Squint	(deg)	Opp sense Rx/Rx, Opp sense Tx/Tx, same sense Rx/Tx and Opp sense Rx/Tx	Specified in degrees.	Beam squint is opposite directions for different sense circular polarizations and is of concern as antenna f/D decreases.
Maximum On-Satellite EIRP spectral density for Low Mid and High frequency across Tx band	**ESD_max**		While compliant with ITU-R S.524-9 for off-axis EIRP spectral density emissions and including radiation pattern shift corresponding to miss-pointing by the pointing error threshold	
Min. Rx X-Pol isolation	**XPol**		within pointing error threshold	
Maximum Cross-Pol EIRP spectral density	**ESD_xpol**		within pointing error threshold	
Skew Angle	**THETA_skew**	The angle between the minor axis of an axially asymmetric antenna beam and the plane tangent to the GSO arc.	for asymmetrical antennas, specify maximum skew angle for which ITU-R S.524-9 may be met or alternatively the reduced on-axis EIRP spectral density.	May be useful when defining maximum PSD at various skew angles for asymmetrical antennas

Table 7.5-2 System Level Performance Terminology				
Phrase	**Term**	**Definition**	**Required parameters**	**Comments**
Temperature rating	**Temp**	Temperature at which all specs are met		
Antenna Noise Temperature	**Ta (deg K)**	Ta, Antenna noise temperature assuming two hemispheres (Tsky, Tground).	30deg elevation, 5K Sky, 290K ground. State elevation angle at which Noise Temperature is specified. Worst noise temperature across band unless specified at frequencies.	Some specs call for a wall behind the antenna so 3 quadrants appear as Tground State elevation angle at which Noise Temperature is specified. Worst noise temperature across band unless specified at frequencies.
Maximum Linear EIRP	**EIRP_lin**	The maximum EIRP such that the spectral regrowth does not exceed a criteria (typically 25 dB) for the intended modulation type(s) often BPSK or QPSK.		
Harmonics		specify in dBc		
Spurious		specify in dBc		
Phase Noise		specify in dBc at frequency offsets from 1 Hz to 1 MHz		

Table 7.5-2 (continued) System Level Performance Terminology				
Phrase	**Term**	**Definition**	**Required parameters**	**Comments**
Transmit Frequency Accuracy		specify in ppm if internal reference or state external reference required.		
Transmit Frequency Stabilty		specify in ppm/24 hours if internal reference or state external reference required.		
Reference - External or Internal options		Specify if external reference input is possible or required. Specify level and impedance of external reference.		
Transmit to Receive Isolation	**(dB)**	Minimum isolation between transmitter output and LNA/B input.	Define feed port isolation, transmit, and receive filtering.	
Transmitter Gain and adjustment range	**G_transmitter**			
Receiver Gain and adjustment range	**G_receiver**			
Transmit IF Interface	**F_if**	Interface frequency range, levels, and return loss		
Receive IF Interface	**F_if**	Interface frequency range, levels, and return loss		

Table 7.5-2 (continued) System Level Performance Terminology				
Phrase	**Term**	**Definition**	**Required parameters**	**Comments**
Pointing System Type	**(narrative)**	GPS, Inertial Nav, dead reckoning, beacon track, beacon assist	What equipment is included and what additional is required?	
Antenna Type	**(narrative)**	reflector, centre fed, offset, passive/active array, symmetrical or asymmetrical		
Operational Altitude	**Alt (ft / m)**	operation altitude (ft or meters)		
Operational Humidity	**RH**	% relative		
Certifications, Approvals, Licences	**(narrative)**	FCC, Brazil, Japan Telec, EU, WGS Cert, Inmarsat GX, Eutelsat, SES, DO-160, FAA, Mil-Std-164, 810G, etc		

Table 7.5-3 Transmitter / Receiver Performance Terminology

Phrase	Term	Definition	Required parameters	Comments
Receiver Temperature	**Tr (degK)**	Tr = Post antenna/feed noise temperature referenced to LNA/B input.		
LNB Noise Figure		Worst case noise figure in operating band		Over frequency and temperature
Minimum G/T	**G/T**		Across Rx band and including pointing loss when miss-pointed by the error threshold State elevation angle at which Noise Temperature is specified. Worst noise temperature across band unless specified at frequencies.	
Minimum EIRP	**EIRPmin**	across Tx band and including pointing loss when miss-pointed by the error threshold		

Table 7.5-4 Positioner Related Performance Terminology

Phrase	Term	Definition	Required parameters	Comments
Pointing accuracy	**THETA_pointing (deg)**	For auto-point systems, this is maximum pointing error before terminal mutes transmit carrier. For SOTM systems, pointing accuracy may be provided as a probability function or CDF.		
Pointing Error Threshold	**THETA_mute (deg)**		above which transmission is muted within 100ms	
Standard Motion Profile	**(narrative)**	Motion environment in which terminal meets operational specifications.	Motion profiles include the ones developed for this ESA study by Fraunhofer. Other profiles include Maritime Class A Churchville B, improved roads, Aeronautical, Mil-Std-810G angular (pitch, roll, yaw) acceleration and velocity Environments: aero, maritime, ground mobile	
Pointing Availability	**A (percent)**	Availability under motion.	as defined by the percentage of time the system under test did not exceed the pointing error threshold when subjected to the standard motion profile	

In four preceding tables cover specification terminology for all classes of VSAT terminal (stationary VSAT installations auto-deploy, SNG services as well as SOTM terminals). We have highlighted terminology relevant to SOTM terminals in bold font.

7.6 GVF-MRA subgroup of Satellite Operators Minimum Antenna Performance Requirements (SOMAP)

The GVF is pleased to report that a group of leading satellite operators have defined Minimum Antenna Performance Requirements for satellite ground stations. Their efforts – which are complementary to ESA's terminal-testing project with Fraunhofer and the Global VSAT Forum (GVF) -- have been made through the Satellite Operator Sub-Group of GVF's Mutual Recognition Arrangement Working Group (MRA-WG). The letter below is an update to ESA from the Satellite Operator Sub-Group.

The MRA Working Group's members, including antenna manufacturers, value-added resellers and satellite operators, will coordinate implementation of the Satellite Operator Sub-group's Requirements to strengthen and harmonize antenna testing in the satellite industry.

As a preamble to the letter which was sent to ESA, the GVF expressed appreciation for ESA's support for improvements to the use of "Satcom On the Move" terminal equipment, and we will continue to coordinate with your organisation throughout the initiative's implementation.

The text from the satellite operator subgroup letter to ESA is presented on the following page.

To : European Space Agency (ESA)

From : Fulvio Fresia, F2SatConsulting/Eutelsat
Fred Ho, AsiaSat
Anja Ellerbrock, SES
Fritz Schurig, Eutelsat
Mark Steel, Inmarsat
Václav Zvonař, SES
Ruben Marentes, Intelsat

December 13th, 2016

GVF-MRA subgroup of Satellite Operators Minimum Antenna Performance Requirements (SOMAP) and ESA

Dear Members of ESA,

Thank you for your interest in our SOMAP project and your request for more transparency.

At the beginning of 2013 our SOMAP group started discussions with the aim to agree on a set of antenna performance data that could represent the absolute minimum for satellite communication. In the following paragraphs you will find a brief description of our objectives and considerations.

The Minimum Antenna Performance Requirements will not have an impact on the minimum standards currently set by individual satellite operators, which are higher in every aspect. They represent the cases for exceptions. If a satellite operator decides not to consider their own minimum requirements but accept lower performance levels, then the Minimum Antenna Performance Requirements should be met. The Minimum Antenna Performance Requirements will not have an impact on common interests in the satellite industry or on requirements for satellite capacity to be exercised. They will be introduced with a significant time margin towards implementation, and a subsequent broad communication exercise directed to organizations in the satellite industry, customers, potential customers and antenna manufacturers. Clarity in communication and reasonability are the main objectives.

Antenna Manufacturers should recognize that our project is not to be seen as an initiative to eliminate low-cost products from the market, or to raise manufacturing costs to an unreasonable level. However, the implementation of a clear benchmark for minimum quality products should be seen as an initiative of satellite operators to merely protect their assets and to ensure a reasonably interference free RF environment for the future.

It needs to be emphasized that without a reasonable set of manufacturer's data regarding a particular antenna model, it is not possible for satellite operators to strictly implement the contractual and intersystem coordination agreements.

We see a change of applications mainly in the Comms-On-The-Move (COTM) section with an impressing variation in the performance of antenna systems. Since no model performs like another, securing manufacturer's performance data per antenna system is absolutely essential for satellite operators.

We expect the number of COTM antenna systems to access the fleet to increase significantly, as we assume that mobile applications will use a significant part of space capacity in the future.

The set of requirements the SOMAP group has defined are moderately low, in essence they reflect a set of antenna performance data that are just acceptable in the most relaxed conditions:

- *In an orbital slot that does not have a satellite with identical coverage and frequency range in its vicinity.*
- *On a satellite that does not have a cross-pol transponder to the targeted transponder.*

Under these conditions, the argument may arise that it is not likely that any service could produce interference to other services. However, the operational environment in geostationary orbit changes all the time and a questionable antenna model that operates without causing interference today, may cause interference tomorrow – either in a different orbital slot, or if the neighbouring orbital slot has undergone changes.

If nothing is being done in the near future to change the current situation, manufacturers of quality products will start to question their own approach to the matter. The manufacturers may and possibly will look for ways to save production costs as a result, which would be a development that is not desirable for satellite operators, who naturally prefer quality products to access their fleet.

The SOMAP group reached out to the Global VSAT Forum (GVF) with the request to motivate and steer antenna manufacturers to list a minimum set of data on their product datasheets. In recent years, the descriptions of the products have become more and more commercially orientated, so that satellite operator's engineers search in vain for technical data which are relevant to their link analyses, like Transmit / Receive Gain, Figure of Merit, Cross-polarization and Axial ratio information as well as overall product limitations. This initiative is currently ongoing and will be introduced to the public in parallel with the Minimum Antenna Performance Requirements.

In view to full visibility and participation in the on-going SOMAP project, the signature of an NDA is mandatory. To maintain our co-operation in absence of an NDA, ESA is kindly invited to forward a related inquiry and/or comments (if applicable) to the SOMAP working group for further consideration.

Yours sincerely,

Fulvio Fresia, Fred Ho, Anja Ellerbrock, Fritz Schurig, Mark Steel, Václav Zvonař and Ruben Marentes

It is anticipated that the restrictions of the NDA will be lifted thereby enabling the performance recommendations from the SOMAP group to be disseminated to the market place and integrated in to the performance recommendations for the ESA ARTES AO-7913 Study.

8. Conclusions

This activity aimed at defining a common way to specify and verify Satellite Communication On-The-Move SOTM Terminals. Without such a consistent way, it is difficult for service providers, satellite operators and end users to clearly understand the capabilities of the product. Lengthy expensive trails have been always the way to evaluate the product's performance. This led to suboptimal growth of the SOTM market. The results of this activity are believed to help move the SOTM market away from the characteristics of a niche market and towards a more established, consumer and manufacturer friendly one.

Standards and type approvals once mutually recognised by the members of the value chain will simplify the route to market and reduce cost. In this study standard type approvals to evaluate the different components as well as the overall performance of a SOTM terminal were developed.

The study started by locating the major inefficiencies and sources of resource waste in the SOTM value chain. In another step, the different contributors to the SOTM market including operators, service providers, Value Added Resellers (VAR) and manufacturers were approached in individual interviews to get their feedback and how they appreciate the emergence of unified standard testing procedures for SOTM terminals. The market feedback was evaluated and the importance of issuing standard type approvals widely admitted was evident.

The requirements of implementing the standard type approvals were assessed. Facilities available in the market were analysed w.r.t. their ability to apply the standard procedures. The Fraunhofer Facility for Over-the-air Research and Testing FORTE was introduced as a leading example in that field. The different components of FORTE were described and its ability to evaluate the different parts in the SOTM terminal as well as the overall system performance was demonstrated.

The results of implementing the proposed standard type approval and test procedures at FORTE using a commercial of-the-shelf SOTM antenna were presented. The tests were witnessed by the antenna manufacturer as well as by GVF.

Extensions and further developments of FORTE were discussed in order to enhance its capabilities and make it ready to cover the needs of the growing and promising SOTM market.

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