EXECUTIVE SUMMARY REPORT

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4000137481/22 /NL/GLC/zk	**"Extending Qualification Range of S Band Diplexer Regarding RF Power"**	**WiRan Sp. z o. o.**
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ABSTRACT:

An S-Band diplexer designed for CubeSat applications designed over the course of the original contract has been redesigned and improved. Main focus was put on improving power handling, higher multipactor threshold and overall improvement of several parameters. Although it redesign seemed successful, tested peak power handling performance has not been increased.

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ESA12 – Executive Summary Report

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NA	NA	NA	NA	NA

Acronym and abbreviation list

FEP	Fluorinated ethylene propylene
RF	Radio Frequency
RL	Return Loss
IL	Insertion Loss
ISO	Isolation (RF)
VNA	Vector Network Analyzer
TVAC	Thermal and Vacuum Chamber
CC	Climatic Chamber
EQM	Engineering Qualification Model

DSx	S-Band Diplexer, variant undefined
DUT	Device Under Test
IMI	Incoming Material Inspection
SE	Shielding Effectiveness

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1 Scope of the document

This document is the compact summary of the „Extending Qualification Range of S-Band Diplexer Regarding RF Power" project, presenting a brief overview, findings, conclusions and possible future developments of the project.

2 Background

The previous contracts, titled "Design, production and tests of an Engineering Model of S-band diplexer for CubeSat nanosatellites" and „S-Band Diplexer for Cube-Sat – CCN" resulted in production of several units of a compact diplexer designed for CubeSat applications. Those units have good RF parameters, especially high level of isolation between RX & TX bands, but do not handle high power; they were limited to less than 3W. The design required modifications to allow higher power handling. Additionally, it was to be validated by test.

3 Specification requirements

A comparison of the old requirements with the new specifications may be found in Table 1. Required return loss on all ports was to be improved by 2 dB, power handling was to increase by 12 W.

Table 1 Previous and New specifications

Parameter	Previous (developed earlier)		New (target to be developed in this project)		
	Diplexer A	Diplexer B	Diplexer A	Diplexer B	unit
RX frequency range (UL)	2025-2067,5 (2025,83-2067,28)	2067,5-2110 (2067,27-2108,71)	2025-2067,5 (2025,83-2067,28)	2067,5-2110 (2067,27-2108,71)	MHz
TX frequency range (DL)	2200-2245	2245-2290	2200-2245	2245-2290	MHz
Isolation at RX frequency range (UL)	>80		>80		dB
Isolation at TX frequency range (DL)	>80		>80		dB
Insertion Loss at TX_f_{center}/f_{edge}	1/1,2		1/1,2		dB
Insertion Loss at RX_f_{center}/f_{edge}	1,2/1,5		1,2/1,5		dB
Return Loss (all ports)	>18		>19		dB
power handling in TX	3		15		W
operating temperature range	-40/+60		-40/+75		°C
Weight	<240		<240		g

Maximum X/Y linear dimension [excluding connectors]	<98	<98	mm
Maximum height Z [excluding connectors, including tuning screws]	30	30	mm
RF interface	SMA female connectors	SMA female connectors	-

4 Design process

Base design (DSx) has been deeply investigated using CST Particle Studio and Spark 3D, focusing on multipactor breakdown and corona breakdown. Once critical regions have been identified, a series of coupons has been defined, manufactured and tested for SEY. These coupons corresponded to different possible technologies of surface treatment of resonator structures. The results of SEY tests were used for further set of analysis. As the expected improvements from surface treatment technology appeared to be not satisfactory to reach power goals defined in specification, metal tuning screws in TX filter have been replaced with dielectric (sapphire) tuning screws, additionally. The whole filtering structure required redesign then. Tuning range and thermal performance was simulated to make sure the new structure meets all requirements of specification. It was possible to keep the outline of the base design (DSx). Once designed, the engineering models have been manufactured and tested.

5 Test & Analysis results of the new diplexers

The EQMs of the new version was put through a series of tests which allowed to determine the design's compliance with specifications. EQMs are listed below in Table 2:

Table 2 EQM identification table

EQM#	SN	description
EQM#1	055-ESA12B-0001	a diplexer in variant D with sapphire tuning screws and FEP coated ends of strips
EQM#2	055-ESA12B-0002	a diplexer in variant D with only sapphire tuning screws
EQM#3	049-DSB-0001	a diplexer developed before this project, being COTS offered by WiRan, TRL9

5.1 S-parameters performance

S-Parameter of two frequency variants of the diplexer are presented in Figure 1, including DUT#1.

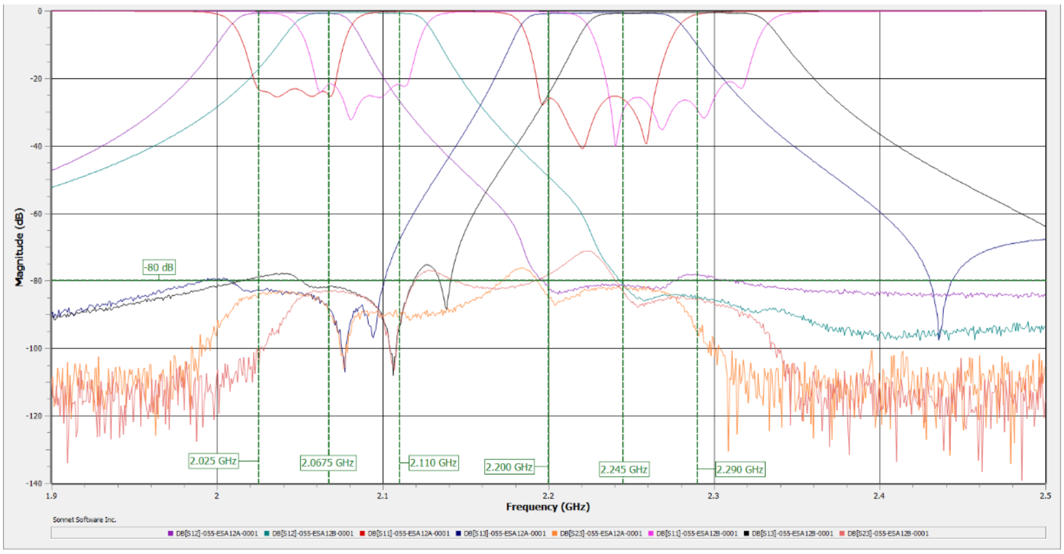

Figure 1 S-parameters of both frequency variands of the diplexer

5.2 Mechanical test

Random vibration test (in X, Y and Z axes) was performed on the EQM#1 unit. S-Parameters after the tests for the EQM#1 are given in Figure 2.

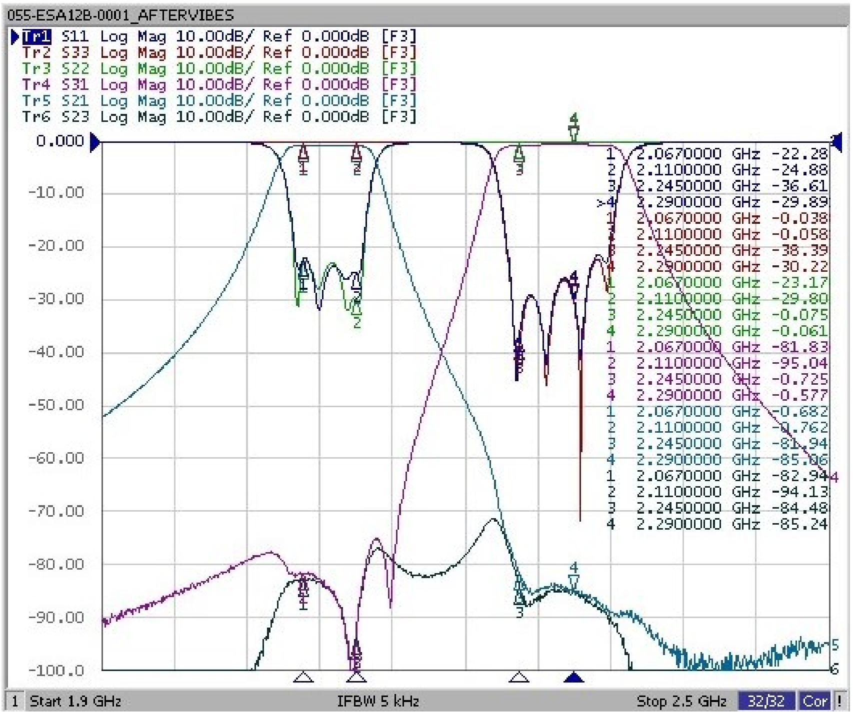

Figure 2 S-parameters of EQM#1 after Random Vibrations Test

5.3 Thermal cycling

The device is supposed to work properly in its operational temperature range, which is -40°C to +75°C. Thermal Cycling has been performed for EQM#1 and EQM#2. Thermal tests allowed to determine compliance with this requirement. The test were conducted in a climatic chamber. Example results for EQM#1 are shown in Figure 3. Figure 4 shows temperature profile of Thermal Cycling.

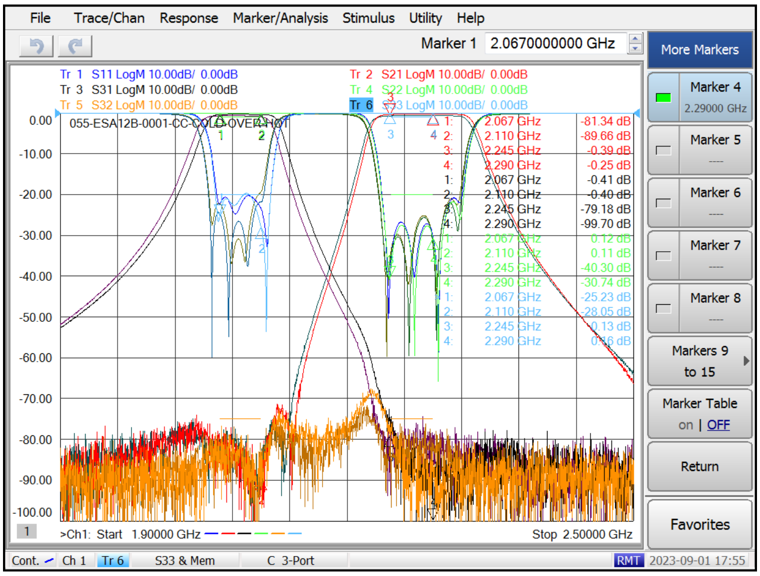

Figure 3 S-parameters of EQM1 in Cold over Hot

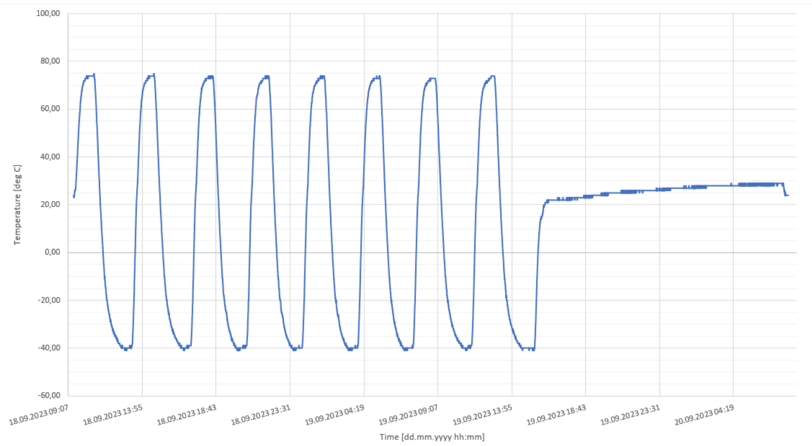

Figure 4 Temperature profile

5.4 Power test

Important aspect to be tested was the power handling capabilities of the device. This test was performed only for EQM#1. DUT has been placed in adiabatic carton box and then in climatic chamber that was set with +75°C. Temperatures are plotted in Figure 5. Please note that on the beginning of the test power was set on 15 Watts and after 2h and 20 mins power was increased to 20 Watts. The unit passed the power test successfully, as its electrical performance was still compliant with specifications after the test.

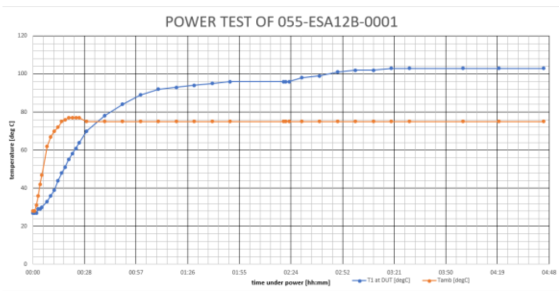

Figure 5 Measured DUT & ambient temperatures over time for 15 & 20 Watts of power

5.5 Multipactor & Corona analysis and test

Comparison of the analysis and tests results may be found in Table 3 and Table 4. Analysis were performed on equivalents models of EQM#1, EQM#2 and DSB (previous design of S-Band diplexer).

Table 3 Comparision of analysis and test results of multipactor

	EQM#1	EQM#2	EQM#3
Expected multipactor breakdown power in 2023	84,5 W	66,9 W	13,9 W
Tested multipactor breakdown power (takes into account (SMP + SMA) adapter loss of 0,21dB)	15,1 W	14,3 W	12,0 W
Analysis after investigation in 2024-02	26,5 W	12,75 W	13,9 W

Table 4 Comparision of analysis and test results of corona

	EQM#1	EQM#2	EQM#3
Analysis	1,7 W (@4mbar)	1,3 W (@4mbar)	1,5 W (@4mbar)
Test	2,5 W (@4mbar)	2,25 W (@4mbar)	2,5 W (@4mbar)

6 Compliance Table

Table 5 lists compliance for each requirement.

Table 5 Compliance table for S-band diplexer

Parameter	Diplexer variant ESA12A (specification)	Diplexer variant ESA12A (EQM) compliance	Diplexer variant ESA12B (specification)	Diplexer variant ESA12B (EQM) compliance	Unit
RX frequency range (UL)	2025-2068	C	2067-2110	C	MHz
TX frequency range (DL)	2200-2245	C	2245-2290	C	MHz
Isolation in TX and RX	>80	C	>80	C	dB
Insertion Loss at TX_fcenter/fedge	1/1,2	C	1/1,2	C	dB
Insertion Loss at RX_fcenter/fedge	1,2/1,5	C	1,2/1,5	C	dB
Return Loss (all ports)	>19	C	>19	C	dB
Power handling	15	NC	15	NC[1];	W
Operating temperature range	-40/+75	C	-40/+75	C	°C
Weight	250	C	250	C	g
Maximum X/Y linear dimension	<80	C	<80	C	mm
Maximum height Z	30	C	30	C	mm
RF interface	SMA female	C	SMA female	C	-
SE	70dB in S band, 30 dB up to X, 20dB up to Ku	Not tested	70dB in S band, 30 dB up to X, 20dB up to Ku	PC[2]	dB

[1] MP breakdown at 10W@-40degC, multipactor safe operation level of 2,5W (6dB margin); corona safe operation up to 0,5W

[2] Compliant in S band (>80dB), noncompliant for C, X bands

7 Conclusions

The diplexer has been analyzed and redesigned. Engineering models have been manufactured and tested. Test results differ seriously from expectations, presenting power performance similar to initial. An investigation has been performed to find the root cause. Main goal of the project has not been achieved, but multipactor and corona performance of production version of the diplexer and new version, developed in this project, has been verified by test.

Anyway, the diplexer is still commercially successful and more than 20 pcs have already been delivered and ca. half of them launched and operated successfully. Meanwhile, WiRan started another parallel activity (COMPACT S-BAND DIPLEXER FOR SMALL SATELLITES TTC APPLICATIONS (ARTES AT 5E.023)) where even more compact 5W S band spurious free diplexer is developed. It is expected that either the result of ARTES project will replace the diplexer developed and tested in this GSTP project or that the technical solutions applied there will be adopted in the base diplexer. Thus it is expected that main goal of this activity will be reached anyway in 2025/26.

List of attachments

i. **none**

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