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QUALITY ANALYSIS OF FLEXIBLE COAXIAL CABLES IN FREQUENCY RANGE 400 TO 3000 MHZ FOR MASS PRODUCTION

Bachelor's thesis

Supervisor: Eduard Petlenkov

Professor

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TALLINNA TEHNIKAÜLIKOOL
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PAINDLIKE KOAKSIAALKAABLITE KVALITEEDI ANALÜÜS SAGEDUSALAS 400 - 3000 MHZ MASSTOOTMISEKS

Bakalaureusetöö

Juhendaja: Eduard Petlenkov
Professor

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Author’s declaration of originality

I hereby certify that I am the sole author of this thesis. All the used materials, references to the literature and the work of others have been referred to. This thesis has not been presented for examination anywhere else.

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Abstract

The aim of this work is to analyse the quality and behaviour of flexible high-frequency coaxial cables in the mass production of high-frequency equipment in the frequency range from 400 MHz to 3 GHz.

The second chapter discusses the basics of coaxial cable, what it is when it was created and applied. Also, in this chapter will be information on the structure and main components of the coaxial cable. In addition, the general and popular types of this cable are described.

The third chapter contains information about the description of the specifications of the coaxial cables selected for verification. And a comparison of these cable specifications with each other.

In the fourth chapter, we learn from what stages verification consists of.

The fifth chapter is devoted to data and analysis of direct verification. We compare which types of coaxial cable have better performance during verification process and why.

This thesis is written in English and is 50 pages long, including 6 chapters, 41 figures and 10 tables.

Annotatsioon

Paindlike koaksiaalkaablite kvaliteedi analüüs sagedusalas 400 - 3000 MHz masstootmiseks

Selle töö eesmärk on analüüsida elastsete kõrgsageduslike koaksiaalkaablite kvaliteeti ning käitumist kõrgsageduslike seadmete masstootmisel sagedusvahemikus 400 MHz kuni 3 GHz.

Teises peatükkis käsitletakse koaksiaalkaabli põhitõdesid, mis see on, kus seda loodi ja rakendati. Tuleb infot koaksiaalkaabli struktuurist ja põhilistest komponentidest. Lisaks räägin kaabli üldistest ja populaarsetest tüüpidest.

Kolmas peatükk räägib verifitseemiriseks valitud koaksiaalkaablite spetsifikatsioonidest ning erinevate kaablite võrdlusest.

Neljas peatükkis kirjeldan verifitseerimise etapid detailsemalt.

Viies peatükk on eraldatud andmetele ning verifikatsiooni analüüsimisele. Võrdleme, mis tüüpli kaablid töötavad paremini ning miks just nii.

Lõputöö on kirjutatud inglise keeles ning sisaldab teksti 50 leheküljel, 6 peatükki, 41 joonist, 10 tabelit.

List of abbreviations and terms

PE	Polyethylene
PTFE	Polytetrafluoroethylene is a synthetic fluoropolymer of tetrafluoroethylene
VSWR	Voltage standing wave ratio
VNA	Vector network analyser
RF	Radio frequency
S-Parameter	Scattering parameters
RL	Return loss
IL	Insertion loss
SF	Sucoflex
H+S	Huber+Suhner

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1 Introduction

Currently, at most all people use information technology in many sectors of their lives. Mobile communications, GPS navigation, the Internet, many of us constantly use these inventions, which give us the opportunity to communicate with our family, relatives, friends. High-frequency telecommunication equipment is more and more flooded with cellular base stations around the world. Huge companies that produce high-frequency telecommunication equipment during its testing, one way or another, are constantly dealing with coaxial cables of different manufacturers and types.

As a test engineer of high-frequency radio equipment, I constantly come across coaxial cables of different manufacturers and types. Touching on the topic of high-frequency coaxial cables, I am most interested in flexible high-frequency coaxial cables, especially the quality of these cables, which are directly involved in testing high-frequency equipment and are connected directly to the test product. In this case, the coaxial cable is manually connected to the test product by the operator. When connecting and disconnecting, the cable bends a little, so it should be flexible, reliable, durable with stable frequency characteristics.

It would be interesting for me to verify several flexible high-frequency coaxial cables from different manufacturers in the mass production of high-frequency equipment from 400 MHz to 3 GHz. In the process of verification, it is necessary to identify which cables can be exploited longer and more stable in the mass production of high-frequency equipment in the selected frequency range by manually connecting the cable to the test product.

In this thesis, I will consider several popular manufacturers and types of flexible high-frequency coaxial cables, their comparison with each other. I will also inform about the verification stages that the selected cables will go through. Will compare the changes in frequency characteristics, specifically S. Parameters, such as return loss, insertion loss and phase deviations after time, testing high-frequency products in mass production. In addition, after verification, it will be seen which cables are able to take place in mass production, and which are not and why.

The difficulty of this work is to correctly formulate steps in the verification process, to constantly monitor and timely respond to physical and electrical deviations of selected cables.

2 Basics of coaxial cables

2.1 Coaxial cable definition

Coaxial cable - an electric cable of a special configuration. The main feature of this type of electric cable is the ability to transmit signals as efficiently as possible without loss of electromagnetic radiation, which has made coaxial cable an indispensable tool for transmitting high-frequency signals.

2.2 First mention

Coaxial cable was first used in a transatlantic cable installation in 1858, but officially theoretically described and patented in 1880 by British engineer, physicist and mathematician Oliver Heaviside.

2.3 Cable structure

The general structure of the coaxial cable is the presence of four basic elements, which are indicated in Figure 1.

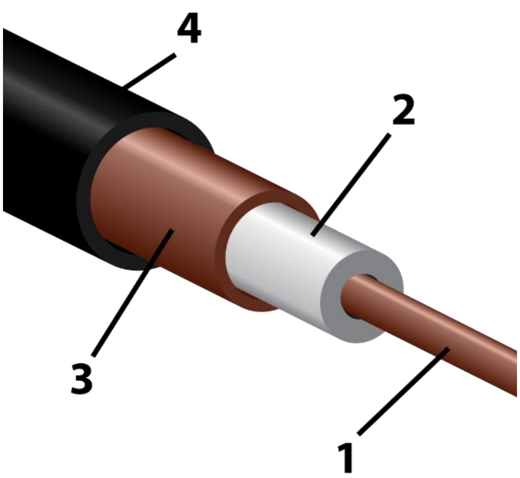


Figure 1. Cable structure.

1 - center conductor (inner)

2 - dielectric layer (insulation)

3 - screen (external conductor)

4 - insulating sheath

Layers description:

1 - central conductor (inner)

Consists of a single or twisted into a spiral stranded wire, the tubes of which can be of different conductive material (often copper, copper alloy, aluminium, etc.). To improve performance at high frequencies, the inner conductor may be silver plated.

2 - dielectric layer (insulation)

Can be made of solid plastic, foam plastic or air with gaskets supporting the inner wire. A solid polyethylene (PE) insulator is often used for lower-loss cables. Solid Teflon (PTFE) is also used as an insulator and exclusively in cables designed for tightness. Dielectric demarcate cable conductors and ensures their coaxial location inside the structure.

3 - screen (external conductor)

Usually use a copper braid (gives flexibility), sometimes the braid is silver-plated. It is common to use a thin foil shield coated by a wire braid. The shield protects the inner conductor from electromagnetic interference and prevents signal leakage.

4 - insulating sheath

Polymer protective sheath or other insulating material. The shell protects against external influences (moisture, dirt, mechanical stress).

2.4 Types of coaxial cables

Coaxial cables are divided by impedance, most popular are 75 Ohms and 50 Ohms. Scientific experiments have revealed that the maximum power handling is achieved with a 30 Ohm coaxial cable, however lowest signal attenuation is achieved using a 77 Ohm cable. 50ohm was chosen as a compromise between power-handling capability and attenuation. In situations where it is necessary that the signal as efficiently as possible (low losses) pass through the cable while losing a very weak signal power, usually 75 Ohm cable used. Cables with 75 Ohm are mostly used for video signals, while 50 Ohm cables tend to be used for data and wireless communications.

There are many types of coaxial cables, they differ from construction, environmental, mechanical and electrical specifications. All these cables also have different sizes, shielding, attenuation and the amount of power with which it can handle.

Further you can find the list of some common types of coaxial cable include and their short description.

- Hard line coaxial cable
- Flexible coaxial cable
- Semi-rigid coaxial cable
- Formable coaxial cable
- Rigid coaxial cable
- Twin axial cable
- Triaxial cable

Hard line coaxial cable is usually larger in diameter than other forms of coaxial cable. These cables can be used in high-strength signal transmission.

Flexible coaxial cable is the most common type, can be bent and moved according to the configuration. For greater flexibility, the central conductor is made stranded, and the dielectric is made of more rigid material.

In a semi-rigid coaxial cable, the outer sheath is usually made of solid copper, for better shielding, and the dielectric is made of PTFE for better characteristics at high frequencies. This cable is not designed to bend after initial formation.

Formable coaxial cable - in this cable instead of a rigid metal sheath, a flexible one is used, which allows bending and changing the shape of the cable.

Rigid coaxial cable consists of two concentric mounted copper tubes that are supported at fixed intervals by means of PTFE supports that do not bend. To turn or bend, use adapters or elbows at an angle of 45 and 90 degrees.

Twinaxial cables have two central conductors with single outer core and dielectric. The advantages are the reduction of losses and magnetic noise.

A triaxial cable to which an additional copper braid is added, which is grounded and is a shield. That is, it unloads the inner core from the currents of the ground loop and capacitive field. This cable has a large bandwidth, reduces losses and strain on the cable.

3 Specifications of selected for verification coaxial cables

3.1 Gore. Cable product code: 0S-N01-N01-1500

Connector type: N (male) – N (male)

Length: 1500 mm

Figure 2. Product code description. Gore.

Since 1976 Gore introduced their microwave assemblies for demanding applications in such directions as aerospace, test, defense, telecommunications and general purpose. The cables of this manufacturer are very reliable, have high internal strength, in addition, they show high phase and amplitude stability with flexure.

Electrical properties:

Table 1. Electrical properties. Gore 0S.

Maximum Frequency (GHz)	18
Typical VSWR	1,19:1
Typical Insertion Loss (dB)	1,13
Impedance (Nominal) (Ohms)	50
Typical Phase Stability (degree)	±2,0
Typical Amplitude Stability (dB)	<±0,05
Dielectric Constant (Nominal)	1,4
Velocity of propagation (Nominal) (%)	85

Shielding Effectiveness (dB through 18 GHz)	>100
Time Delay (Nominal) ns/cm	0,04

Mechanical / Environmental properties:

Table 2. Mechanical properties. Gore 0S.

Center Conductor	Stranded
Overall Diameter (mm)	7,7
Nominal Weight (g/m)	147,6
Minimum Bend Radius (mm)	25,4
Typical Flex Cycles	100,000
Temperature range (°C)	-55 to +125
Crush Resistance (kgf/cm)	44,6

Cable design (consists of 9 elements):

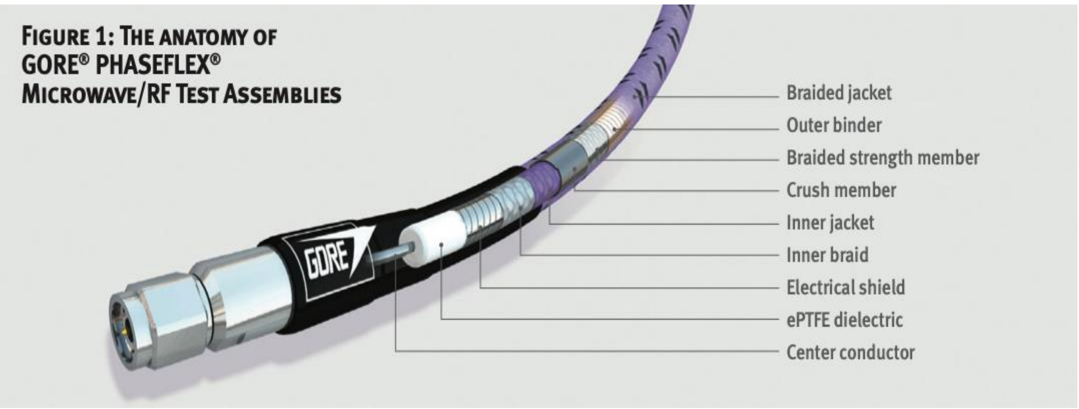


Figure 3. Cable construction. Gore 0S.

Features indicated by the manufacturer in the documentation for this type of cable.

Features:

- Phase and amplitude stability
- Crush, torque and kink resistant
- Phase matching options
- Replaceable interface options/adapters
- Key Benefits:
- Longer calibration intervals
- Longer field-service life
- Suited for parallel or comparative measurements
- Reduced risk of assembly damage

3.2 Huber + Suhner. Cable product code: SF-526S-11N-11N-1500

Cable type: Sucoflex 526S

Connector type: N (male) – N (male)

Length: 1500 mm

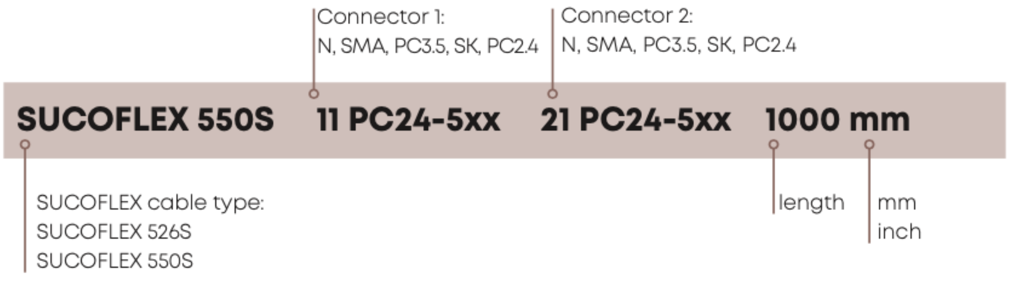


Figure 4. Product code description. Huber + Suhner.

According to the manufacturer. SUCOFLEX 500 series will provide better phase and amplitude stability versus flexure, movement, temperature and tensile stress. This type of cable is excellent for test and measurement up to 26,5 GHz.

Electrical properties:

Table 3. Electrical properties. Huber + Suhner SF-526S.

Maximum Frequency (GHz)	26,5
Impedance (Ohms)	50
Velocity of propagation (Nominal) (%)	77
Time delay (ns/m)	4,32
Shielding Effectiveness (dB through 18 GHz)	90
Typical Return Loss (dB)	25
Typical Insertion Loss (dB/m)	1,63
Typical Amplitude Stability (dB)	±0,05
Typical Phase Stability (degree)	±3

Mechanical / Environmental properties:

Table 4. Mechanical properties. Huber + Suhner SF-526S.

Center Conductor	Stranded
Overall Diameter (mm)	7,7
Minimum Bend Radius (mm)	25,4
Typical Flex Cycles	>100,000
Temperature range (°C)	-55 to +125
Nominal Weight (g/m)	144

Cable design (consists of 9 elements):

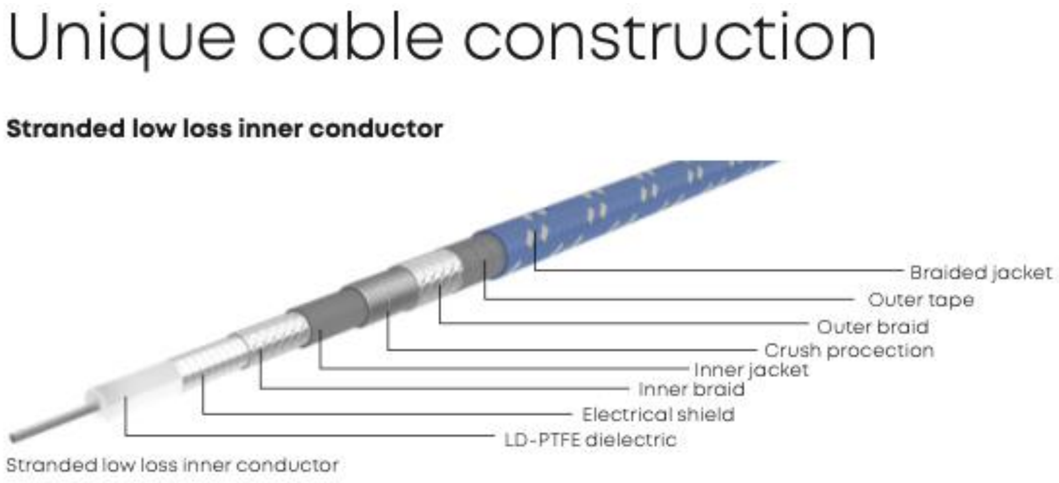


Figure 5. Cable construction. Huber + Suhner SF-526S.

Construction

	Material	Detail	Diameter
Centre conductor	Copper, Silver plated	Strand, Low-loss	
Dielectric	PTFE (Polytetrafluoroethylene)		
Outer conductor	Copper, Silver plated	wrapped Foil, 100%	
Outer conductor	Copper, Silver plated	Braid	
Jacket	FEP (Fluorinated ethylene propylene)		
Armor: Steel wire helix (Spiral)	Steel		
Armor: Steel wire	Steel	Braid	
Jacket	PTFE (Polytetrafluoroethylene)	RAL 5023 - bl	7.7 mm

Figure 6. Cable materials. Huber + Suhner SF-526S.

Features indicated by the manufacturer in the documentation for this type of cable.

Features:

- Applicable up to 26,5 GHz
- Excellent return and insertion loss
- Phase and amplitude stability vs, flexure and movement
- Torque, crush and kink resistance
- Abrasion, moisture and dust resistance
- Precise and repeatable measurements
- Long service life
- Reduce total cost of test with durable, reliable performance

3.3 Rosenberger. Cable product code: LU7-139-1500

Cable type: RTK-162-P

Connector type: N (male) – N (male)

Length: 1500 mm

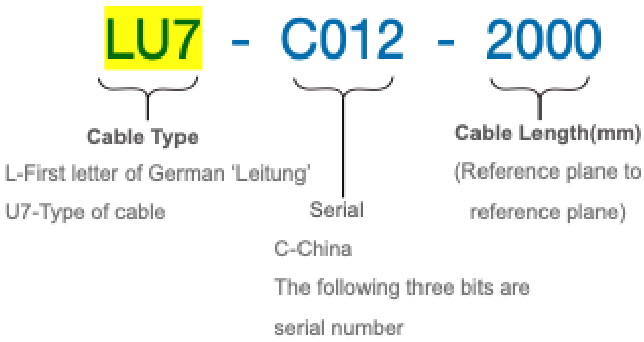


Figure 7. Product code description. Rosenberger.

According to the manufacturer.

He developed a series of cables that is cost-effective, superior amplitude and phase stability. Compared to conventional test cables, Rosenberger high-frequency stable amplitude and phase cables provide superior performance. The cable in question is with a polyurethane jacket, which according to the manufacturer makes the cable very flexible and can withstand high temperatures.

Electrical properties:

Table 5. Electrical properties. Rosenberger RTK-162-P.

Maximum Frequency (GHz)	18
Impedance (Ohms)	50
Velocity of propagation (Nominal) (%)	77

Time delay (ns/m)	4,32
Shielding Effectiveness (dB through 18 GHz)	>100
Typical Return Loss (dB)	≥19
Maximum Insertion Loss (dB/m)	2,03
Typical Phase Stability (degree) 18 GHz	±5

Mechanical / Environmental properties:

Table 6. Mechanical properties. Rosenberger RTK-162-P.

Center Conductor	Stranded
Overall Diameter (mm)	5,33
Minimum Bend Radius (mm)	10
Typical Flex Cycles	>100,000
Temperature range (°C)	-55 to +125
Nominal Weight (g/m)	66

Cable design (consists of 5 elements):

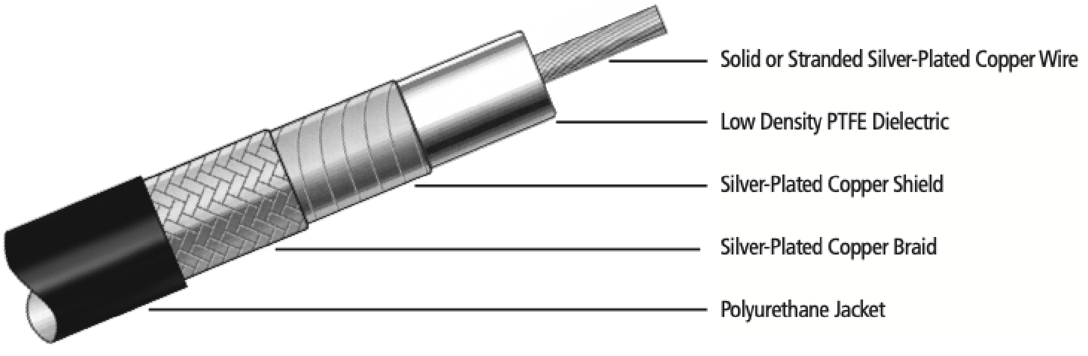


Figure 8. Cable construction. Rosenberger RTK-162-P.

Features indicated by the manufacturer in the documentation for this type of cable.

Product features:

- Outstanding VSWR
- Better amplitude and phase stability
- Smooth Frequency Response
- Flexible cable assemblies, long life characteristic

3.4 Huber + Suhner. Cable product code: SF-104PE-11N-11N-1500

Cable type: Sucoflex 104 PE

Type: N (male) – N (male)

Length: 1500 mm

According to the manufacturer.

The sucoflex 100 series flexible microwave cable provide excellent electrical and mechanical characteristics for static and dynamic applications. In cases where flexibility is critical, SUCOFLEX 104PE type cable should be used.

Electrical properties:

Table 7. Electrical properties. Huber + Suhner SF-104PE.

Maximum Frequency (GHz)	18
Impedance (Ohms)	50
Velocity of propagation (Nominal) (%)	77
Time delay (ns/m)	4,3
Shielding Effectiveness (dB through 18 GHz)	>100
Typical Return Loss (dB)	≥16,6

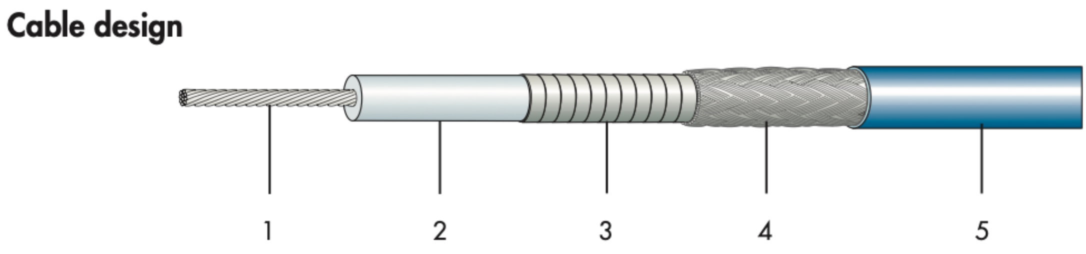
Maximum Insertion Loss (dB/m) to 18 Ghz	1,43
Typical Phase Stability (degree)	±5

Mechanical / Environmental properties:

Table 8. Mechanical properties. Huber + Suhner SF-104PE.

Center Conductor	Stranded
Overall Diameter (mm)	5,5
Minimum Bend Radius (mm)	16
Typical Flex Cycles	>100,000
Temperature range (°C)	-55 to +125
Nominal Weight (g/m)	73

Cable design (consists of 5 elements):



	Description	Material	Diameter
1. Centre conductor	Stranded silver-plated copper wire	CuAg	
2. Dielectric	Low density PTFE	LDPTFE	
3. 1st outer conductor	Silver-plated copper tape, wrapped	CuAg	
4. 2nd outer conductor	Silver-plated copper braid	CuAg	
5. Jacket	Polyurethane, blue	PUR	5.50 mm
Marking	none		

Figure 9. Cable construction. Huber + Suhner SF-104PE.

Features indicated by the manufacturer in the documentation for this type of cable.

Product features:

- Applicable up to 26,5 GHz
- High stability and low loss
- Wide range of connectors
- VNA-specific connectors
- Quick lock nuts

3.5 Comparison of specifications of selected cables.

Electrical properties:

Table 9. Selected cables comparison. Electrical properties.

Cable manufacturer/type/model	Gore 0S-N01-N01-1500	Huber + Suhner SF-526S-11N-11N-1500	Rosenberger LU7-139-1500	Huber + Suhner SF-104PE-11N-11N-1500
Maximum Frequency (GHz)	18	26,5	18	18
Impedance (Ohms)	50	50	50	50
Velocity of propagation (Nominal) (%)	85	77	77	77
Time delay (ns/m)	4	4,32	4,3	4,3
Shielding Effectiveness (dB through 18 GHz)	>100	90	>100	>100
Typical Return Loss (dB)	≥21,2	25	≥19	≥16,6

Maximum Insertion Loss (dB/m) max. Frequency	1,13	1,63	2,03	1,43
Typical Phase Stability (degree)	±2	±3	±5	±5

It should be noted that cable Huber+Suhner SF-526S-11N-11N-1500 is specified up to 26.5 GHz and the electrical properties specified by the manufacturer such as Return Loss, Insertion Loss and Phase Stability are given up to 26.5 GHz and cannot be objectively compared with the electrical properties of the other three types of cables that are specified up to 18 GHz.

As we can see the main differences between the tested cables in Electrical properties are:

- Typical Return Loss.

Gore and H+S 526S have better reflection coefficients than Rosenberger and H+S 104PE.

- Maximum Insertion Loss on max frequency.

Gore and H+S 526S have better indicators of attenuation than Rosenberger and H+S 104PE.

- Typical Phase Stability.

Gore and H+S 526S have a more stable phase than Rosenberger and H+S 104PE.

Mechanical / Environmental properties:

Table 10. Selected cables comparison. Mechanical properties.

Cable manufacturer/type/model	Gore 0S-N01-N01-1500	Huber+Suhner SF-526S-11N-11N-1500	Rosenberger LU7-139-1500	Huber+Suhner SF-104PE-11N-11N-1500
Center Conductor	Stranded	Stranded	Stranded	Stranded
Overall Diameter (mm)	7,7	7,7	5,33	5,5
Minimum Bend Radius (mm)	25,4	25,4	10	16
Typical Flex Cycles	>100,000	>100,000	>100,000	>100,000
Temperature range (°C)	-55 to +125	-55 to +125	-55 to +125	-55 to +125
Nominal Weight (g/m)	147,6	144	66	73

As we can see the main differences between the tested cables in Mechanical properties are:

- Cable overall diameter.

Gore and H+S 526S have a diameter of 7.7 mm (4 extra layers), Rosenberger and H+S 104PE have a diameter of more than 2 mm less - 5.33 mm and 5.5 mm.

- Minimum bending radius.

Rosenberger and H+S 104PE have a minimum bending radius of 10 mm and 16 mm, Gore and H+S 526S have a minimum bending radius of almost 2 times longer - 25.4 mm in both.

- Nominal weight.

Gore and H+S 526S have a weight of 147,6 g/m and 144 g/m (additional 4 layers), Rosenberger and H+S 104PE have a weight of more than 2 times less - 66 g/m and 73 g/m.

Construction.

All four cables have:

- Stranded, copper, silver-plated center conductor
- PTFE (Polytetrafluoroethylene) dielectric except Gore (ePTFE Expanded Polytetrafluoroethylene - own production of GORE)
- Wrapped, silver plated copper foil and silver-plated copper wire braid outer conductors.

Next up are the differences. The fifth and final element in Rosenberger and H+S 104PE cable is polyurethane jacket. However, Gore and H+S 526S cables have five more additional layers: inner jacket (FEP -fluorinated ethylene propylene), crush protection member, braided strength member, outer tape, braided jacket. The main goals of the additional layers are to maximize the stability of the electrical properties, mechanical strength and flexibility of the cable.

4 Verification stages

- Selection of cables for verification.

Four cables of different manufacturers and types are selected. All of those cables have connector type N male - N male and length are 1500mm. Three manufacturers were selected: Gore, Huber + Suhner, Rosenberger. Huber + Suhner selected 2 types of cable. So, Gore 4 pcs of cables, Rosenberger 4 pcs of cables, Huber + Suhner 4 pcs of cables of one type and 4 pcs of cables of another type, in total 16 test cables are obtained.

- Checking the selected cables.

Checking each cable from the RF side (special attention was paid to the amplitude-frequency characteristics and phase-frequency characteristics) and mechanically. For RF verification during all verification time, the PNA-L 5230 vector network analyzer is used. Before cables verification the VNA was successfully calibrated using ECal (electronic calibration) module with actual calibration. If the checking results correspond to the cable specifications, then this cable is suitable for further verification.

- Connecting cables to the test station.

Connection of 16 cables to 4 manual testers (with high volume of production) so that at each station there are 4 cables of different manufacturers and types. The main point is that all cables are connected and disconnected by the operator to the tested product manually. The cable makes a movement and bends a little. All cables are labeled with numbers from one to four for each manufacturer and type of cable.

- Checking of all cables every week.

Rechecking the cables every week. If during the cable checking mechanical damage or any instability of the signal is detected, then such a cable is removed from the station and the checking results are recorded. If during the cable inspection no damage is detected, it continues to participate in the verification.

- End/analysis of verification.

After two months, all remaining cables are forcibly removed from the station, then checked for mechanical and RF damage, and the verification results are recorded.

5 Data of verification process

5.1 Graphs description.

In this chapter, the graphs of the S-parameters (S11, S22, S21, S12) and Phase of all 16 cables that participated in the verification for a maximum of two months will be given below. The frequency range of all graphs (S-parameters and Phase) is from 400 MHz to 3 GHz. The S-parameters graphs show the data of the return loss and attenuation of the cables before the start of verification, indicated as "DB", and at the end of verification, indicated as "DB2". In other words, one can observe a change in the behavior of the signal from the beginning to the end of verification. Magnitude in dB is indicated along the x-axis, frequency in Hz is indicated along the y-axis.

The phase graphs are compiled in this way, 14 points with an interval of 200 MHz in the above range. Here you can see the phase behavior before the start of verification, designated as "DEG", and at the end of verification, indicated as "DEG2", that is, the change in phase behavior from the beginning to the end of verification. The phase in degrees is indicated along the x-axis, and the frequency in Hz is indicated along the y-axis.

5.2 Gore. Cable product code: 0S-N01-N01-1500

Comparing 4 graphs of S. Parameters and Phases for all 4 cables of this type, you can see that the data after 2 months remained almost the same without any deviations. On the mechanical side, visually, no damage was found.

Cable No1

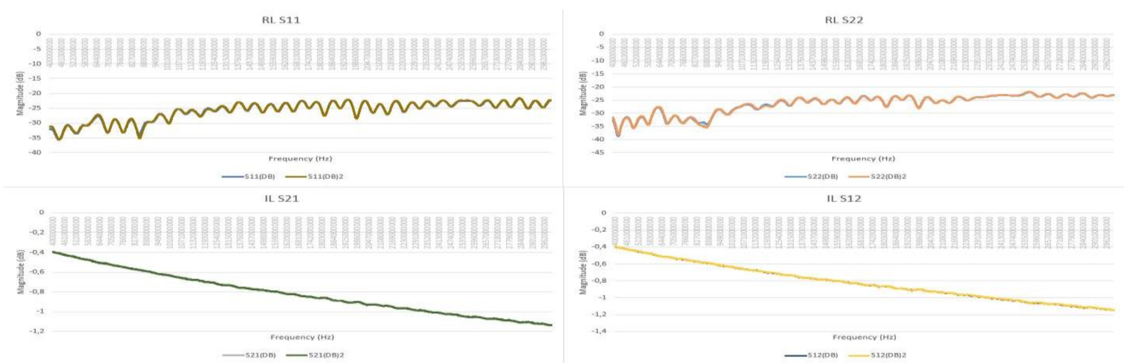


Figure 10. Stability of S-Parameters. Gore cable No1.

Figure 11. Stability of Phase. Gore cable No1.

Cable No2

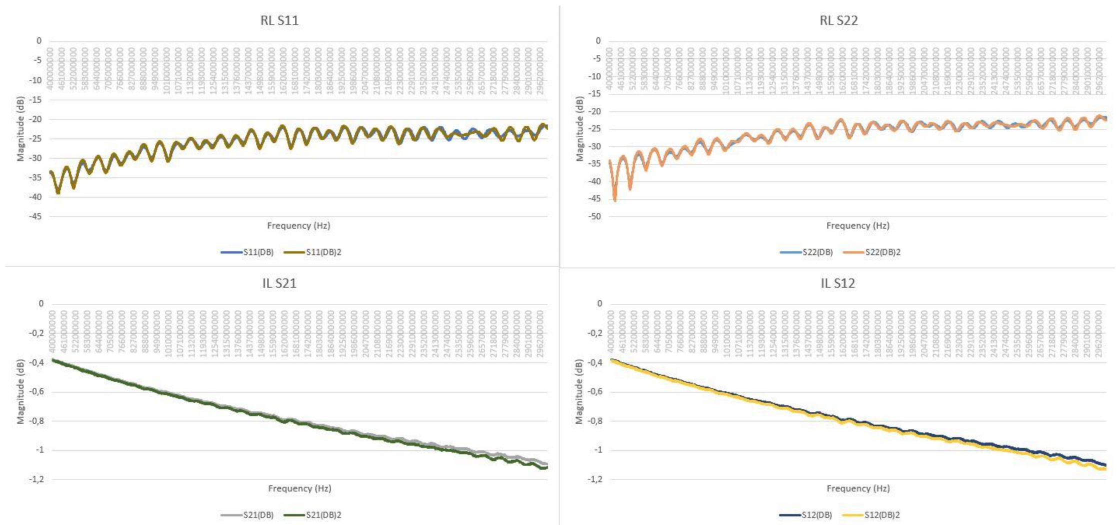


Figure 12. Stability of S-Parameters. Gore cable No2.

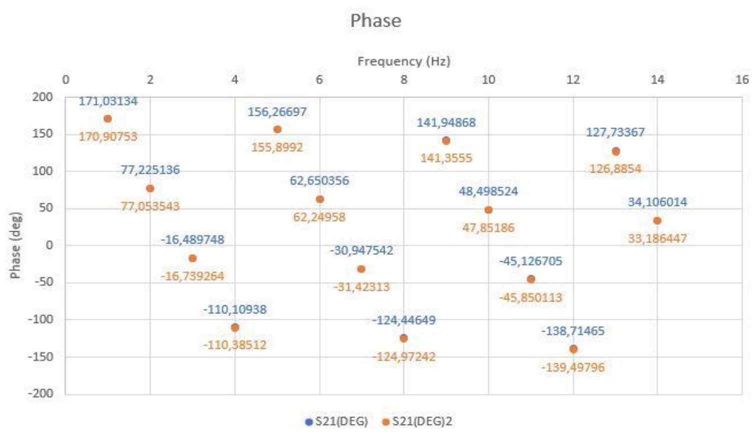


Figure 13. Stability of Phase. Gore cable No2.

Cable No3

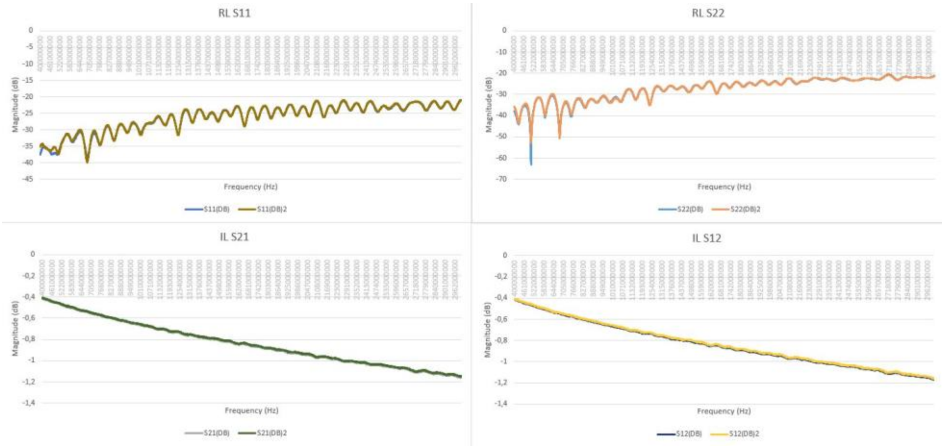


Figure 14. Stability of S-Parameters. Gore cable No3.

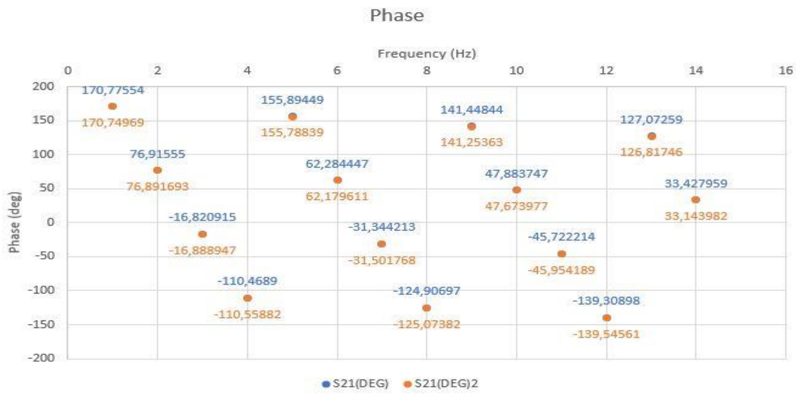


Figure 15. Stability of Phase. Gore cable No3.

Cable No4

Figure 16. Stability of S-Parameters. Gore cable No4.

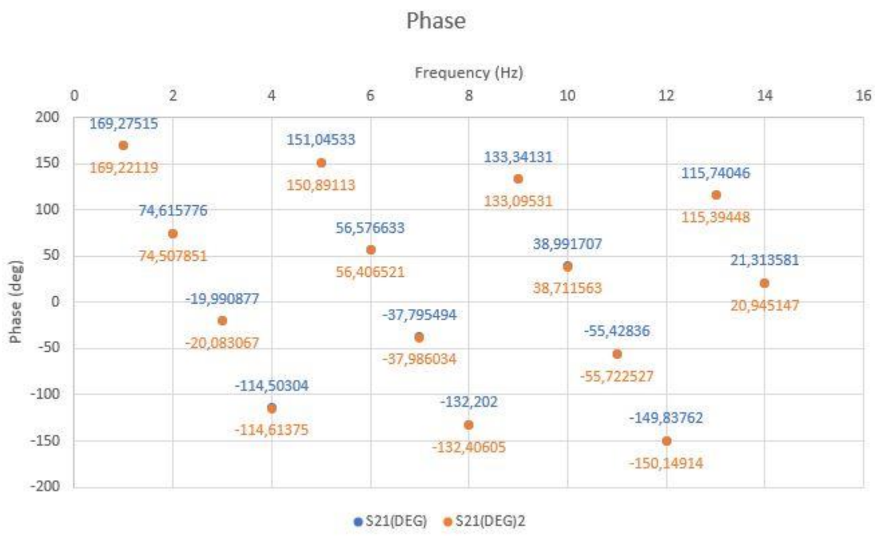


Figure 17. Stability of Phase. Gore cable No4.

5.3 Huber+Suhner. Cable product code: SF-526S-11N-11N-1500

Comparing 4 graphs of S. Parameters and Phases for all 4 cables of this type, you can see the following:

Cable No1 - RL starting with a frequency of 1.8 GHz becomes worse by 1 dB, IL increased very slightly. The phase is stable, the deviation is a maximum of 0.5 degrees.

Cable No2 has a similar situation as Cable No1.

Cable No3 - the minimum deviation of the RL and IL is closer to the end of the frequency range from 2.7 GHz. The phase is stable. The deviation is a maximum of 0.5 degrees.

Cable No4 - RL deteriorated by 2 dB, IL increased very slightly. The phase loses stability starting from 2 GHz.

On the mechanical side, visually, no damage was found.

Cable No1

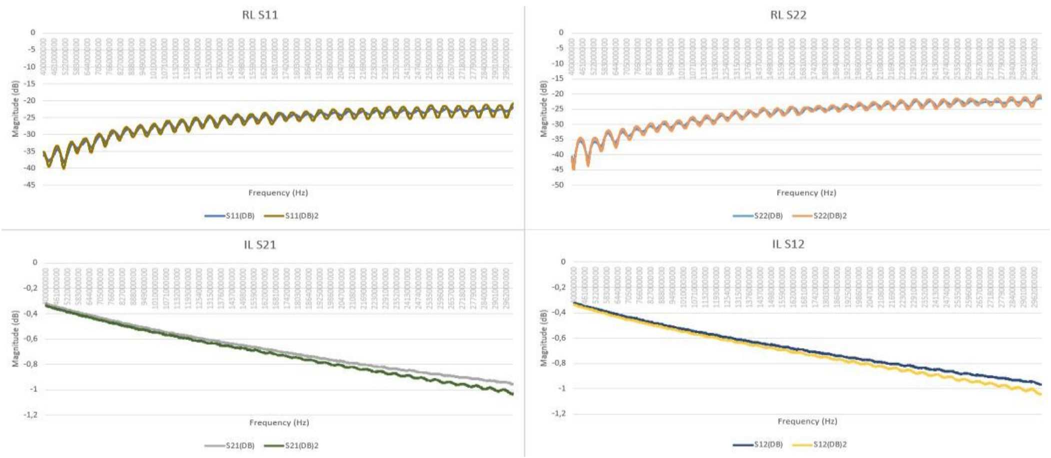


Figure 18. Stability of S-Parameters. Huber + Suhner SF-526S cable No1.

Figure 19. Stability of Phase. Huber + Suhner SF-526S cable No1.

Cable No2

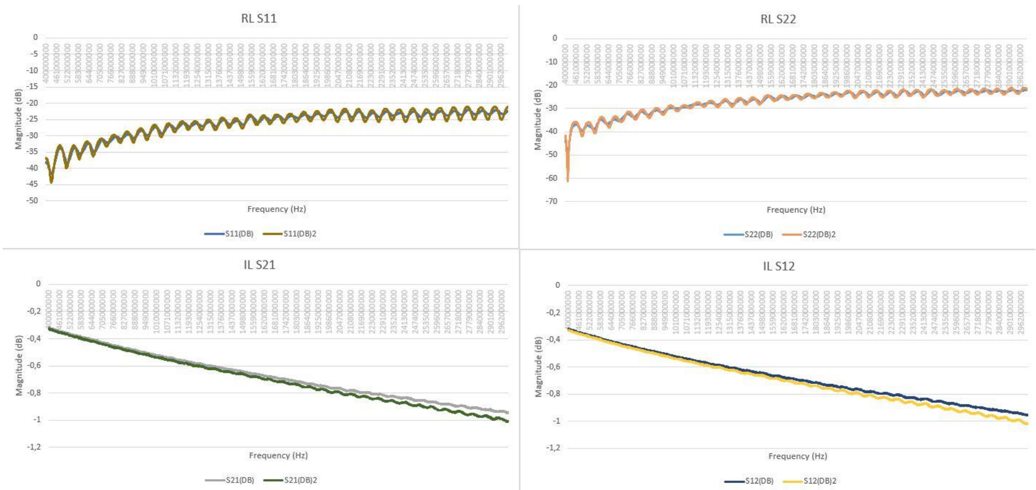


Figure 20. Stability of S-Parameters. Huber + Suhner SF-526S cable No2.

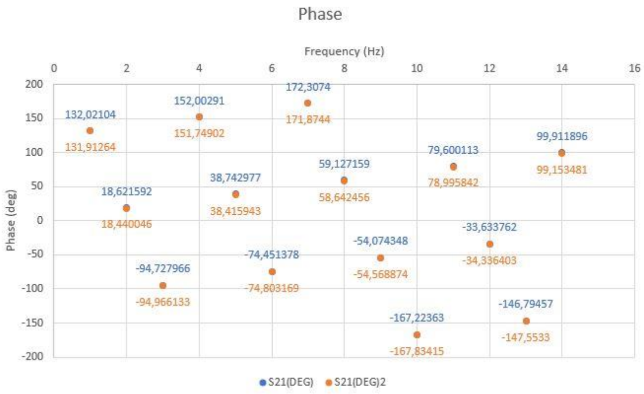


Figure 21. Stability of Phase. Huber + Suhner SF-526S cable No2.

Cable No3

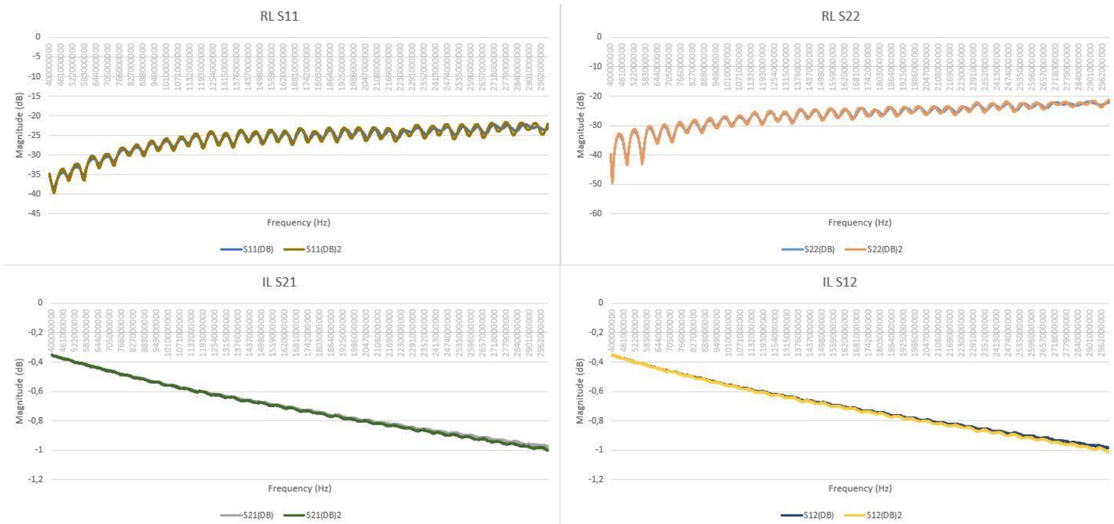


Figure 22. Stability of S-Parameters. Huber + Suhner SF-526S cable No3.

Figure 23. Stability of Phase. Huber + Suhner SF-526S cable No3.

Cable No4

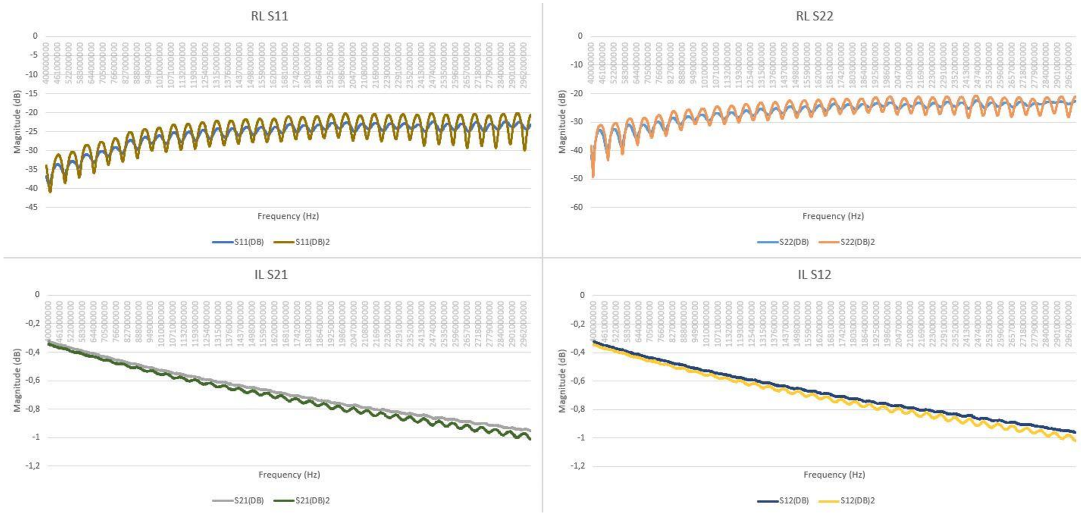


Figure 24. Stability of S-Parameters. Huber + Suhner SF-526S cable No4.

Figure 25. Stability of Phase. Huber + Suhner SF-526S cable No4.

5.4 Huber + Suhner. Cable product code: SF-104PE-11N-11N-1500

Comparing 4 graphs of S. Parameters and Phases for all 4 cables of this type, you can see the following:

Cables No1, 2, and 3 - RL became worse by 1.4 - 1.8 dB, IL increased very slightly. The phase is stable, the deviation is a maximum of 1.5 - 1.8 degrees to the end of the range.

Cable No4 - RL deteriorated by 2.4 dB, IL increased very slightly. The phase loses stability starting from 2 GHz by a maximum of 3 degrees.

On the mechanical side, visually, no damage was found.

Cable No1

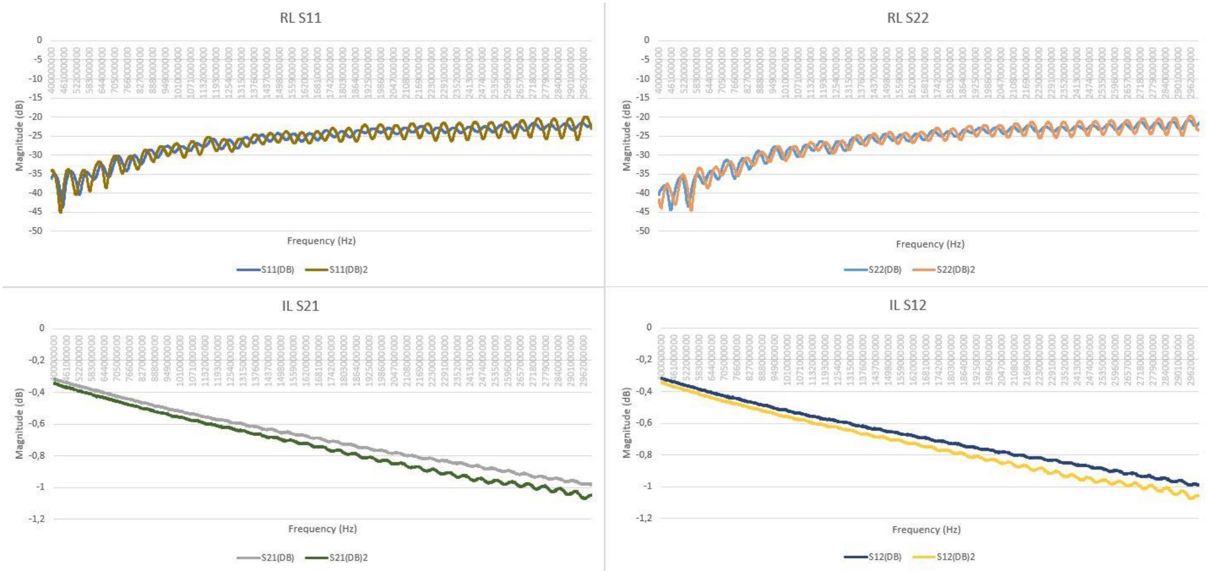


Figure 26. Stability of S-Parameters. Huber + Suhner SF-104PE cable No1.

Figure 27. Stability of Phase. Huber + Suhner SF-104PE cable No1.

Cable No2

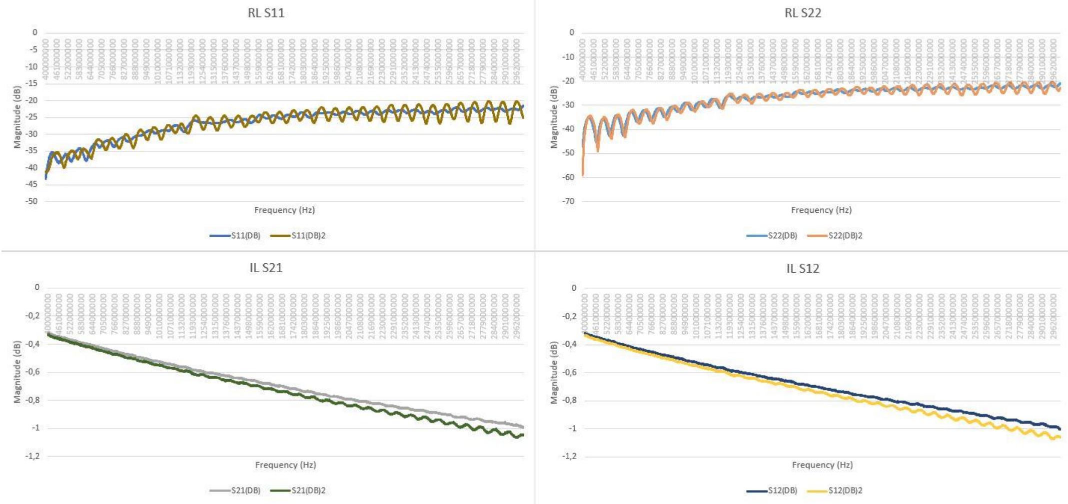


Figure 28. Stability of S-Parameters. Huber + Suhner SF-104PE cable No2.

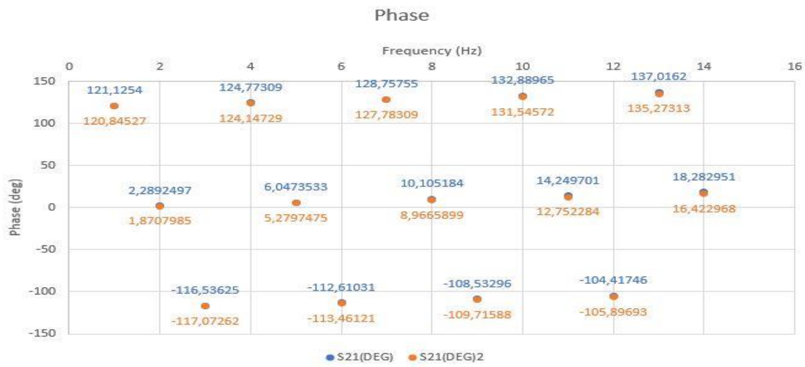


Figure 29. Stability of Phase. Huber + Suhner SF-104PE cable No2.

Cable No3

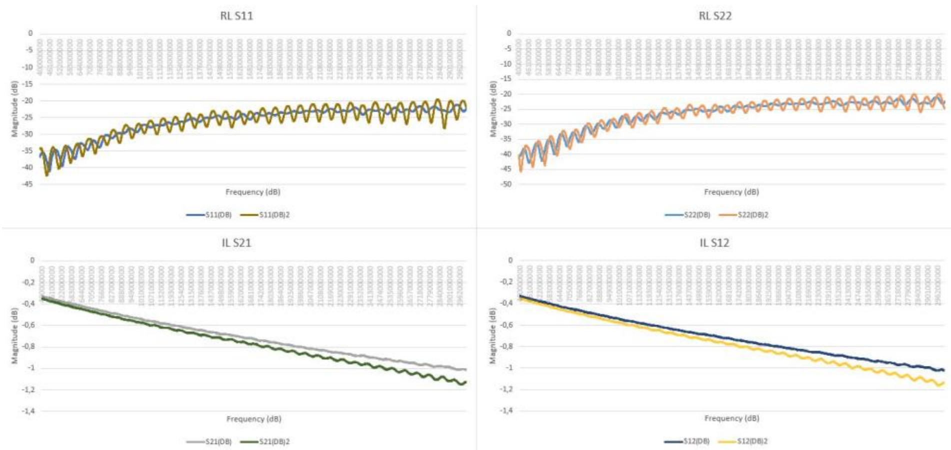


Figure 30. Stability of S-Parameters. Huber + Suhner SF-104PE cable No3.

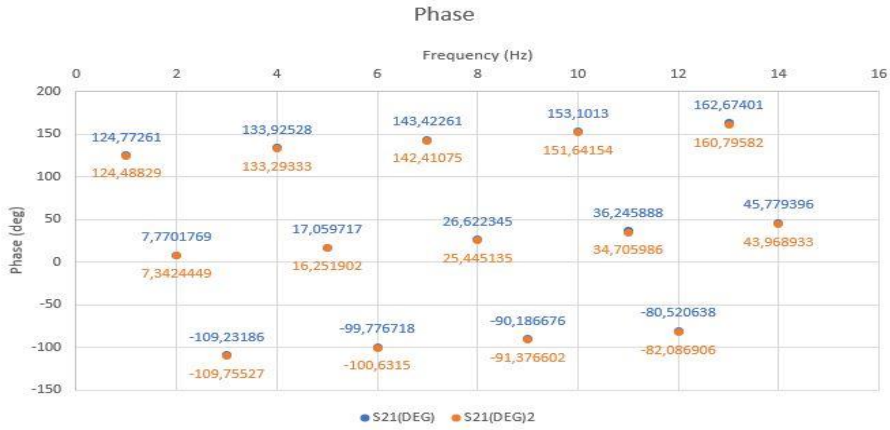


Figure 31. Stability of Phase. Huber + Suhner SF-104PE cable No3.

Cable No4

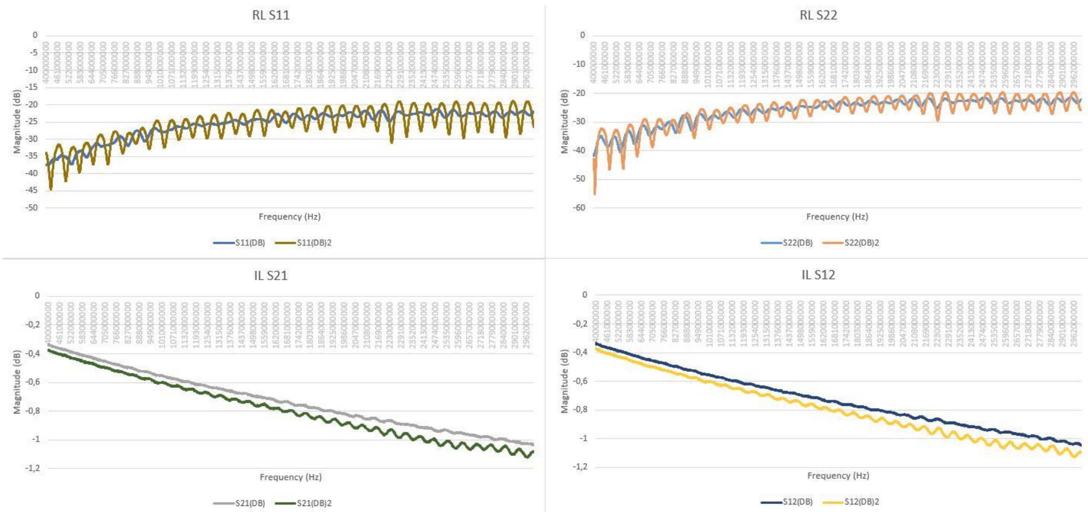


Figure 32. Stability of S-Parameters. Huber + Suhner SF-104PE cable No4.

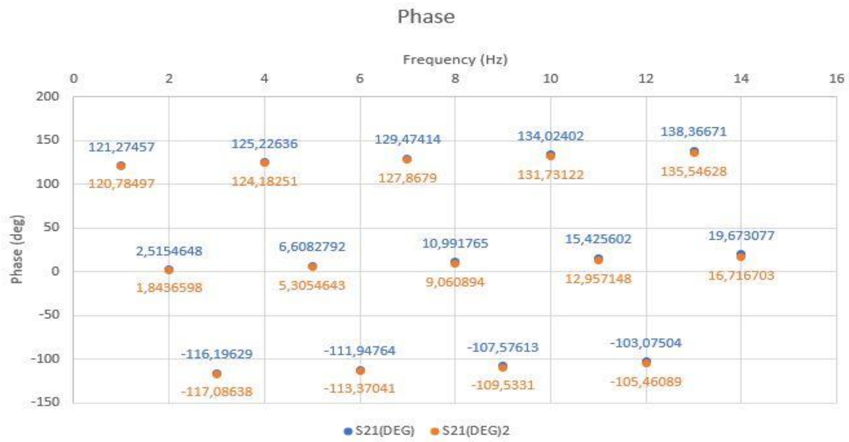


Figure 33. Stability of Phase. Huber + Suhner SF-104PE cable No4.

5.5 Rosenberger. Cable product code: LU7-139-1500

Comparing 4 graphs of S. Parameters and Phases parameters for all 4 cables of this type, you can see the following:

Cable No1 - RL deteriorated by a maximum of 1.5 dB, IL increases very slightly. The phase loses stability, by the end of the range the deviation is a maximum of 4 degrees.

Cable No2 - RL deteriorated by a maximum of 1.7 dB, IL increases very slightly. The phase is stable. Deviation is a maximum of 1.5 degrees.

Cable No3 - RL deteriorated by a maximum of 1.7 dB, IL increases very slightly. The phase loses stability, by the end of the range the deviation is a maximum of 2.3 degrees.

Cable No4 - RL deteriorated by a maximum of 1.6 dB, IL increases very slightly. The phase is stable. Deviation is a maximum of 1.5 degrees.

On the mechanical side, no damage was visually detected.

Cable No1

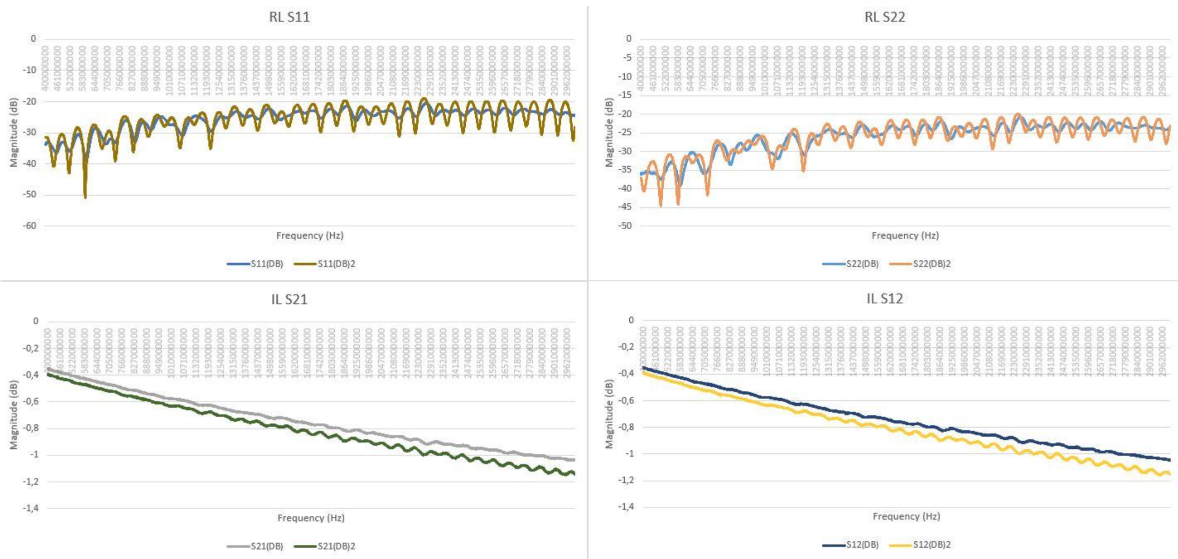


Figure 34. Stability of S-Parameters. Rosenberger cable No1.

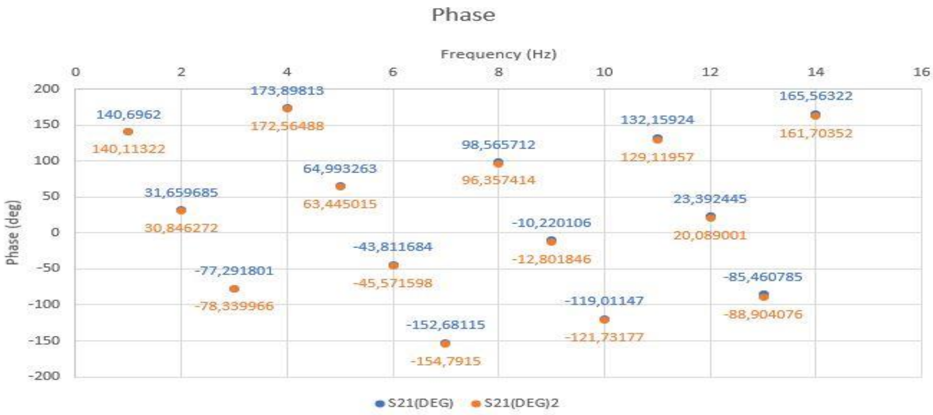


Figure 35. Stability of Phase. Rosenberger cable No1.

Cable No2

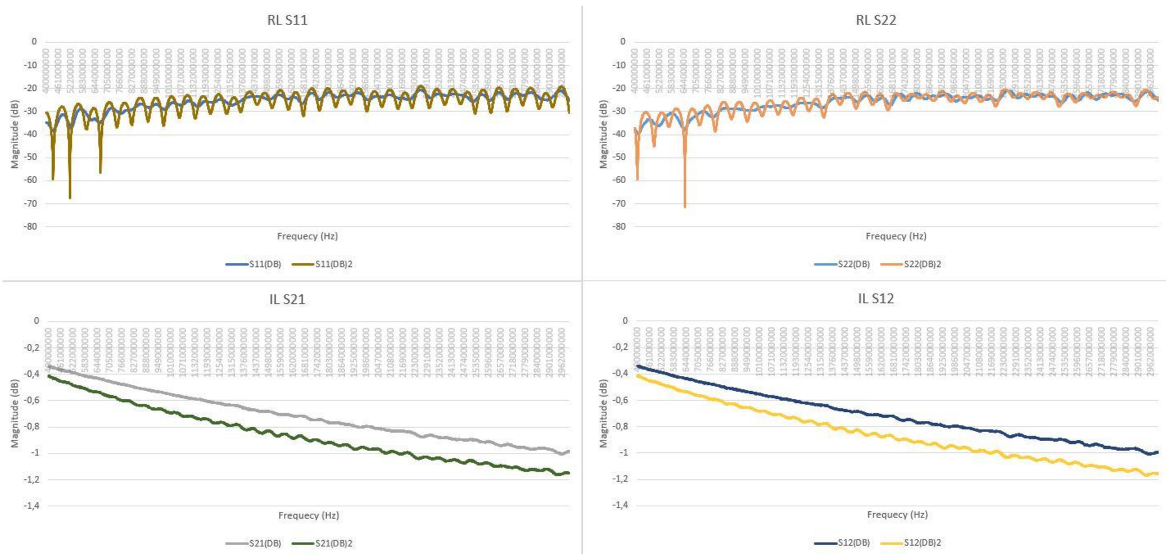


Figure 36. Stability of S-Parameters. Rosenberger cable No2.

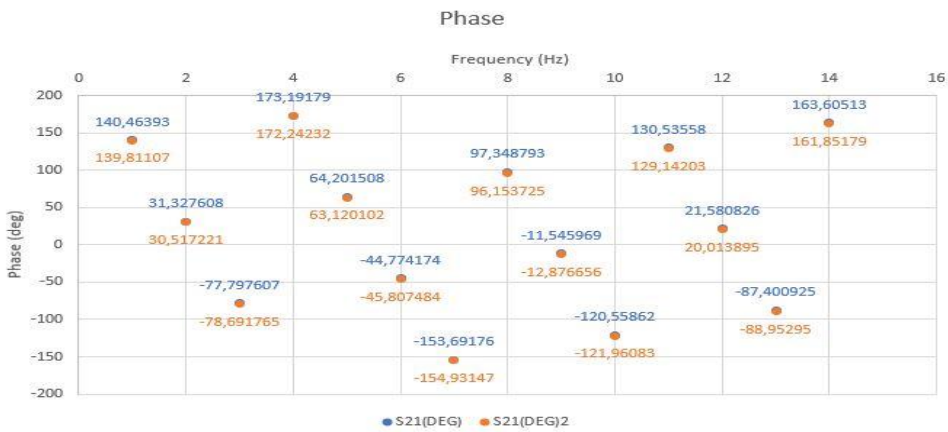


Figure 37. Stability of Phase. Rosenberger cable No2.

Cable No3

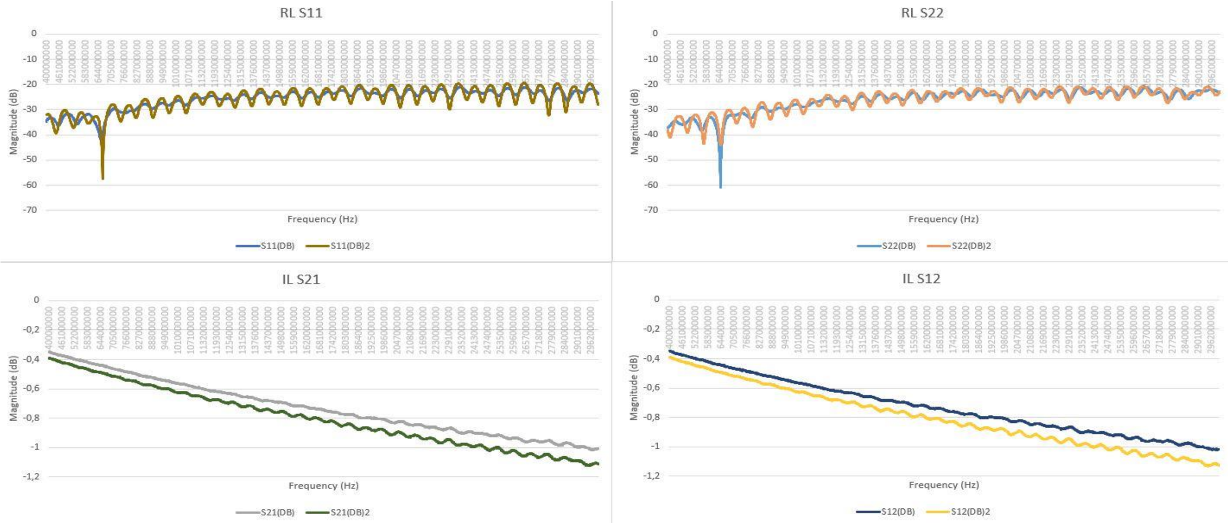


Figure 38. Stability of S-Parameters. Rosenberger cable No3.

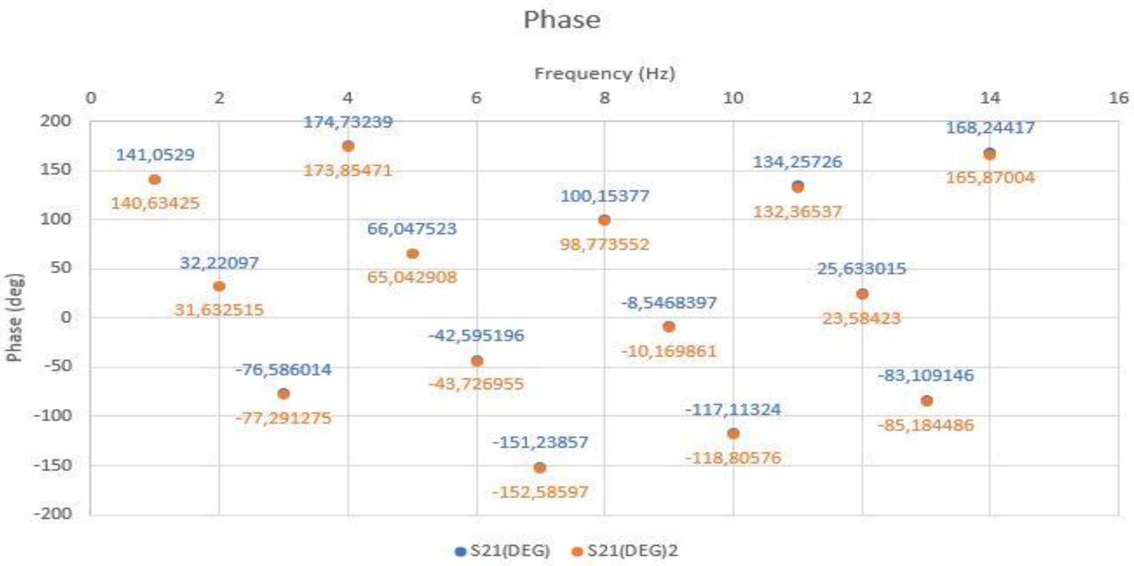


Figure 39. Stability of Phase. Rosenberger cable No3.

Cable No4

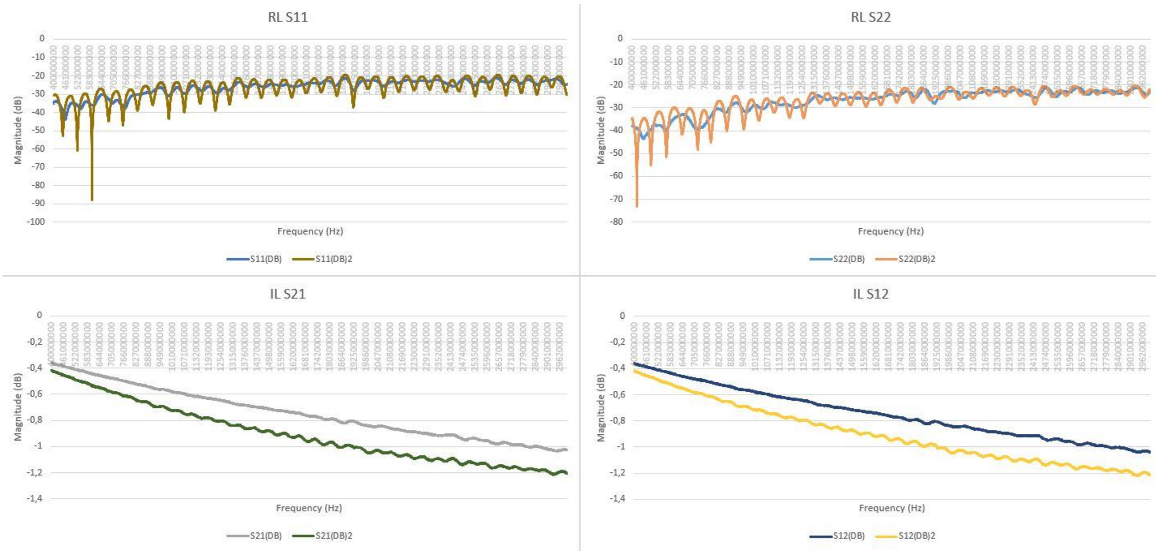


Figure 40. Stability of S-Parameters. Rosenberger cable No4.

Figure 41. Stability of Phase. Rosenberger cable No4.

5.6 Comparison of verification process

All four Gore cables showed themselves best of all during two months of work in production up to 3 GHz. All of them worked in mass production until the end of verification.

All Huber + Suhner 526S cables worked in mass production until the end of verification, also 2 months. After two months, one cable showed not the best frequency characteristics, but when tested for a dynamic test (bending the cable during checking on VNA) according to S. Parameters (RL, IL) the signal was stable.

Two of the four Huber + Suhner 104PE cables worked at the mass production for six weeks, after which they were removed from verification due to the instability of the signal according to S. Parameters during the dynamic test - the RL jumped 2 dB at a frequency from 1.8 GHz, which is categorically not suitable for testing high-frequency products from 1.8 GHz. The remaining two cables were finalized until the end of the verification, after which they were also removed from the station due to signal instability. This type of cable can be used in statics, for example, inside a test station, where it does not make movement.

Two of the four Rosenberger cables worked at the production site for five weeks, after which they were removed from verification due to the instability of the signal according to S. Parameters during the dynamic test - the RL jumped 2 dB at a frequency from 1.5 GHz, which is categorically not suitable for testing high-frequency products from 1.5 GHz. The remaining two cables were finalized until the end of the verification, after which they were also removed from the station due to signal instability. This type of cable can be used in statics, for example, inside a test station, where it does not make movement.

As a result, it turned out that cables Gore and Huber + Suhner 526S, where in addition to the main 4 layers there are 4 additional protective layers, are more suitable (can be used longer and more stable) for mass production of high-frequency equipment up to 3 GHz.

6 Summary

The main goal of my thesis was to analyse the quality of flexible coaxial cables selected for verification in the mass production of high-frequency products in the range from 400 MHz to 3 GHz when manually connecting the cable to the test product. That is, it was necessary to determine which's of the selected cables are better suited for mass production.

At the beginning of the work, we met with coaxial cables. Then we examined several manufacturers of coaxial cables and compared their specifications with each other. After we got acquainted with the stages of verification. We also saw how different types of coaxial cables behave after two months participating in the testing of high-frequency products, and also compared the frequency characteristics of these cables before and after verification.

Based on the comparison result, we found that cables with additional protective layers are more suitable for mass production of high-frequency equipment up to 3 GHz when manually connecting the cable to the test product. Those cables have more stability in electrical properties - in Phase stability and S. Parameters such as Return Loss, Insertion Loss (attenuation).

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