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Eurobalise On-board Equipment, Susceptibility Test Specification

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Foreword

The main body of this specification, and the relevant Annexes designated as "normative", constitute the mandatory requirements for test methods and tools for verification of compliance with the mandatory requirements of the Eurobalise FFFIS (SUBSET-036). Annexes designated as "informative", either provide background information, or outline non-mandatory requirements and optional features.

Contents

1 Scope

This specification is aiming at defining basic test procedures and test tools applicable to the laboratory immunity tests of the Eurobalise transmission functions (also called BTM functionality or simply BTM) of the ERTMS/ETCS On-board equipment.

These immunity tests have the objective to define a laboratory test methodology for compliance verifications of the On-board ERTMS/ETCS constituent to immunity requirements.

The following test cases are considered in this document:

- Immunity test of the combined functions of Up-link data reception, Balise detection and Balise location during simulation of Balise passages.
- Immunity tests of the Balise detection function and of the on-line antenna self-test without simulation of Balise passages.

The H-field interference signals simulated in the air-gap during the immunity tests are of the transient, damped oscillation typology, resembling typical signals emitted underneath the rolling stocks by power traction converters, and CW.

2 Normative References

The following European specifications are applicable references for this document:

Reference	Document	Title
1	UNISIG SUBSET-036	FFFIS for Eurobalise
2	UNISIG SUBSET-085	Test Specification for Eurobalise FFFIS

3 Terminology and Definitions

3.1 Acronyms

The acronyms used in this document correspond to the following list:

Acronym	Explanation
AWG	Arbitrary Waveform Generator
APT	Antenna Positioning Tool
BICP	Bulk Injection Current Probe
BTM	Balise Transmission Module
CP	Current Probe
CRC	Cyclic Redundancy Check
CW	Continuous Wave
DC	Direct Current
DSO	Digital Storage Oscilloscope
EMC	Electro Magnetic Compatibility
ERTMS	European Railway Traffic Management System
ETCS	European Train Control System
EUT	Equipment Under Test
FSK	Frequency Shift Keying
HW	Hardware
LPF	Low Pass Filter
LTMS	Laboratory Test Management System
LTOM	Laboratory Time and Odometer Module
MFP	Magnetic Field Probe
MTIE	Maximum Time Interval Error
NSG	Noise Signal Generator
RF	Radio Frequency
RSG	Reference Signal Generator
SW	Software
WLA	Wide Loop Antenna

3.2 Definitions

In general, the definitions of Ref. [1] (UNISIG SUBSET-036) apply.

4 Introduction

4.1 ERTMS On-board Functionality prone to Disturbance

The interference effect of extraneous signals entering into the receiver bandwidth can be different for different designs. With some generality, the following effects or functions could be inferred:

- The **“Balise Detection Function”** is mostly affected by the average energy entering into the receiver within a given time window. In this case, the interference effect would likely lead to a “false Balise detection” with harmful consequences to the operational reliability.
- The **“On-line Transmission Self-test”** is mostly affected by the average energy entering into the receiver within the time window of the self-test. In this case, the interference effect could lead to temporary failures of the self-test with harmful consequences to operational reliability.
- The **“Data Reception Function”** is mainly affected by the peak energy entering into the receiver within a time window of one or several bits. In this case, the interference effect could lead to unrecognizable Balise telegrams with harmful consequences to operational reliability. The interference can be critical in case of high peak periodical bursts with repetition periods shorter than the telegram duration. The data reception function will be interfered if there are not sufficient amount of undisturbed bits for decoding the telegram.

Evaluation criteria for non-disturbed functionality are further detailed in sections 5.4.1 and 6.1.

4.2 Critical Parameters

In general, there are parameters of the disturbance that may be altered. It has been identified that for the ERTMS on-board technology the most important parameters are:

- The magnetic field intensity
- The self frequency of oscillations
- The damping factor of damped sinusoidal oscillations
- The repetition rate

Further details are found in section 5.3.5 and Annex C.

5 Data Reception and Balise Detection/Location

5.1 General Description

The data reception performance of the BTM function of the ERTMS/ETCS On-board equipment is evaluated in laboratory by simulating dynamic Up-link signal patterns that resemble those resulting by the combined action of the Balise and of the On-board antenna under consideration when it is running at a defined speed.

The dynamic Up-link signal patterns, corresponding to various operational and environmental conditions are built in interference-free environment, following the procedures of section 5.2.3 (Evaluation of Radiation Pattern) and of section 5.2.4 (Creation of Signal Pattern for Dynamic tests) of Ref. [2] (SUBSET-085).

In this context, it is assumed that the dynamic Up-link signal patterns, corresponding to the test conditions of interest, are already available from the Eurobalise functional tests. Transmission tests, similar to those specified in section 5.2.5 of Ref. [2], are then performed with simulation of such Up-link dynamic signals and with the additional superposition of an interference signal of varying characteristics in the air-gap.

The test results consist in the assessment of the impact of the simulated interference typology/amplitude in:

- The overall number of telegrams received during each Balise passage simulation (that gives a measure of the reception reliability).
- The Balise Location accuracy.
- The Balise Detection function.

5.2 Test Set-up

5.2.1 General Layout

The general layout of the set-up recommended for the data reception immunity tests is shown in Figure 1 below.

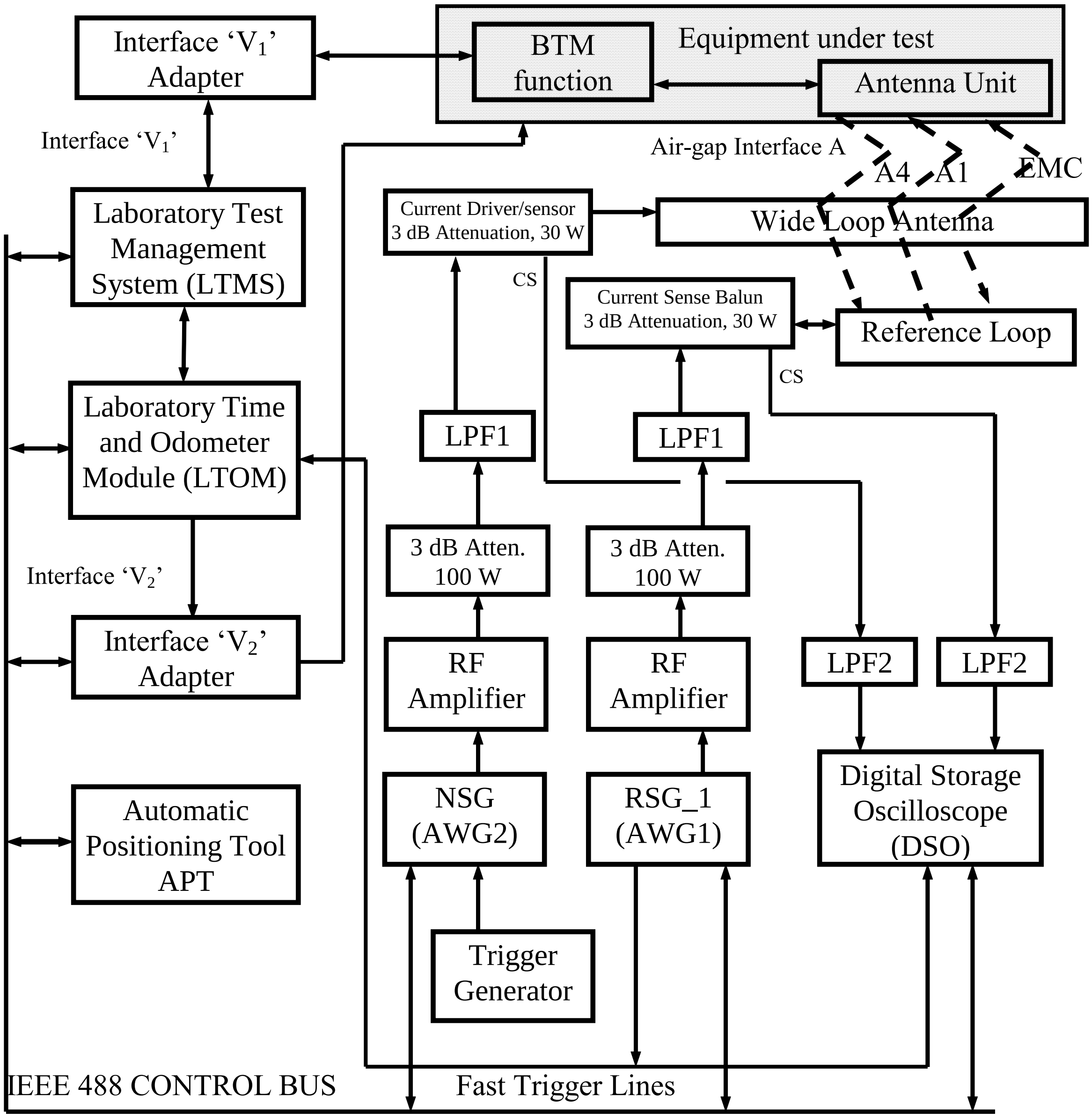


Figure 1: Test set-up for data reception immunity tests

5.2.2 Test Tools

5.2.2.1 Laboratory Test Management System (LTMS)

The Laboratory Test Management System (LTMS) allows the operator to set the On-board transmission equipment under test (the BTM functionality) in the operational mode of interest. It also collects and stores periodical and sporadic reports issued by the same equipment. These reports constitute the raw results of the various test steps.

The LTMS communicates with the BTM functionality via the company specific Interface V_1 Adapter. The data exchanged between the LTMS and the BTM functionality is specified in all details in Annex E1 of Ref. [2].

Additionally, the LTMS provides off-line control of the Laboratory Time and Odometer Module (LTOM), of the Up-link signal Generator (RSG_1), of the Noise Signal generator (NSG), of the Digital Storage Oscilloscope (DSO), and of the Automatic Positioning Tool (APT).

Upon choice of the operator, the LTMS allows manual or automatic control of the test procedures.

More details about the LTMS can be found in Annex D5 of Ref. [2].

5.2.2.2 Laboratory Time and Odometer Module (LTOM)

The Laboratory Time and Odometer Module (LTOM) simulates the train movement according to pre-defined acceleration patterns and provides periodically, via the company specific Interface V_2 Adapter, the BTM functionality with the current time, speed and position information corresponding to the actual train movement.

The LTOM can also provide the Arbitrary Waveform Generator of the RSG_1 with triggering pulses for starting the real-time generation of the dynamic air-gap test signals at pre-defined distance based locations.

Finally the LTOM is able to detect external trigger pulses and precisely stamp them with the train movement coordinates (time, distance and speed) valid at the triggering instant. These coordinates, which typically correspond to the coordinates of the Balise centre location, are stored and made available to the operator for the off-line analysis of the Balise location functionality of the BTM.

Upon choice of the operator, the LTOM allows manual or automatic control of the test procedures.

More details about the LTOM can be found in Annex D1 of Ref. [2].

5.2.2.3 Reference Signal Generator (RSG)

The Reference Signal generator (RSG) is a tool that generates all the input signals necessary for the functional test of the Eurobalise products.

In particular, the sub-set RSG_1 is used for simulating the Up-link Balise signal with the possibility of controlling the time envelope profile and all the relevant electrical characteristics.

The RSG_1 is composed of an off-line SW package, that evaluates and stores the whole set of samples describing each Up-link signal waveform, and of an HW platform that reproduces such waveform in real time.

In this specific case, the RSG_1 generates, by means of one or more Arbitrary Waveform Generators (AWG1), the real-time dynamic Up-link signal corresponding to each test case, with the required electrical characteristics, in response to an external command issued either by the operator or by the LTOM trigger (Balise passage simulation).

The set of samples corresponding to each Balise passage simulation is pre-stored in the internal mass storage of the AWG1. Each set is selected and uploaded into the AWG1 working memory either manually or under control of the LTMS, sufficiently in advance of its real-time use.

Additionally, the AWG1 is programmed to generate a triggering pulse, in correspondence of the centre of the simulated Balise passage. The LTOM, triggered by this pulse, generates the time and distance information (related to the simulated train motion) corresponding to the Balise centre simulation. This information is used for the off-line evaluation of the response delay time of the BTM and of the accuracy of its Balise Location function.

A Vector Signal Analyser might be needed for verification of some characteristics of the simulated Up-link signal.

More details about the RSG_1 can be found in Annex D2 of Ref. [2].

5.2.2.4 Noise Signal Generator (NSG)

The Noise Signal Generator (NSG) generates the interference signal with the specific electrical characteristics required for each test step.

The NSG is composed of an off-line SW package, that evaluates and stores the whole set of samples describing each interfering signal waveform, and of an Arbitrary Waveform Generator (AWG2) that reproduces such waveform in real time.

The set of samples corresponding to each interference pattern is pre-stored in the internal mass storage of the AWG2. Each set is selected and uploaded into the working memory of the AWG2 either manually or under control of the LTMS sufficiently in advance of its real-time use.

More details about the Interference Test Signals are found in Annex C.

The generation of the test signals shall not be synchronised with generation of the Up-link signal, but triggered by the free running Trigger Generator (see section 5.2.2.11).

5.2.2.5 Reference Loop

The Reference Loop, driven with an FSK modulated current, generates an Up-link signal in the air-gap with spatial distribution and polarisation very similar to the one generated by the Balise typology under consideration.

Details about Balise installation constraints can be found in section 5.6 of Ref. [1]. More details about the mechanical and electrical properties of the Reference Loops can be found in Annex H of Ref. [2].

5.2.2.6 Wide Loop Antenna (WLA)

The Wide Loop Antenna (WLA), driven with a properly shaped current, generates a uniform distribution of the interfering magnetic field in the Eurobalise air-gap, with the required level and polarisation.

More details about the WLA can be found in Annex A.

5.2.2.7 Digital Storage Oscilloscope (DSO)

The Digital Storage Oscilloscope (DSO) is used for displaying an image of the current injected into the WLA during the various test steps and, when applicable, of the Up-link current injected into the Reference Loop. It is normally used for checking the correct amplitude and the shape of the signal envelops during the different test steps.

During the simulation of the dynamic Up-link signals, the DSO is externally triggered with the same signal that starts the Balise passage simulation, in order to allow the display and the permanent recording of the used test signals patterns.

5.2.2.8 Antenna Positioning Tool (APT)

The Antenna Positioning Tool (APT) is used to locate the On-board Antenna under test relative to the Reference Loop. The Reference Loop is kept in a defined fixed position that constitutes the origin of the spatial reference system used for defining positions and movements of the On-board antenna.

The APT is automatically controlled in its basic X, Y, and Z movements either in response to the operator’s commands via the Man Machine Interface in “local control”, or in response to LTMS commands in “remote control”.

More details about the APT can be found in Annex D3 of Ref. [2].

5.2.2.9 Auxiliary RF Devices

The RF Amplifiers are used to inject the required current levels into the air-gap transmission units. They shall have sufficient power capability (between 100 and 200 W) and bandwidth (higher than 100 MHz), in order to reproduce the required test signals. They shall also have the possibility to accurately adjust (manually and or automatically) the level of its output.

The 3 dB Attenuators (rated at power levels of 100/30 W) are used for ensuring a source impedance of 50 Ω at the input of the cable connected to the Reference Loop and to the WLA, as well as for attenuating the Tele-powering signal being reflected back to the Power Amplifier from the On-board antenna.

The WLA is current-driven by means of a commercial current injection probe as shown in Annex A. The measurement and DSO visualisation of the current circulating in the WLA can be made by means of a current sensor as shown in Annex A.

The Current Sense Balun is used for minimising the effect of common mode currents between cables and ground. It is equipped with an insulated current sensor that allows visualisation and control of the level of the injected current into the Reference Loop. More details about this balun can be found in Annex H5.4 of Ref. [2].

The Low Pass Power Filters (LPF1) are used to suppress the 27 MHz Tele-powering signal picked-up from the air-gap that could disturb the measurements. Their cut-off frequency is about 10 MHz and the required attenuation at 27 MHz must be higher than 50 dB. They must be able to handle signal power of the order of 50/100 W at both inputs and present minimal distortion for the intended test signals. More details on this type of filters can be found in Annex E.

The Low Pass Filters (LPF2) are also used for suppressing the 27 MHz potentially disturbing the measurement of the injected currents. They have to handle power levels of up to 0.5 W. Their cut-off frequency is about 10 MHz and the required attenuation at 27 MHz must be higher than 80 dB. They must present minimal distortion for the monitored test signals. More details on this type of filters can be found in Annex F1 of Ref. [2].

It is important that all RF transmitter cabling is of low loss double shielded type (e.g., RG 214). Furthermore, the cables shall be “de-bugged” using suitable ferrite clamps, evenly spaced along the cables, at distances less than 70 cm.

5.2.2.10 Magnetic Field Probe (MFP)

The Magnetic Field Probe (not explicitly shown in Figure 1) is defined in detail in Annex B. This device is the reference for quantifying disturbance fields generated by the WLA, and the reference for quantifying emission levels underneath the vehicle.

During quantification of emission levels underneath the vehicle, it is not mandatory to always use the MFP, but possible to also use other antennas/loops. However, in such a case it is the full responsibility of the individual party to properly link all the relevant characteristics of other antennas to the characteristics of the MFP.

For the purpose of the measurements defined in this specification, the antenna loop positioned at 75 mm distance from the screen plate shall be used.

5.2.2.11 Trigger Generator

The trigger generator shall trigger generation of the Interference Test Signals. The triggering signal shall have the following characteristics:

- A sinusoidal signal giving the repetition rates of Annex C.
- Frequency modulated by the modulation frequency 200 Hz.
- Peak frequency modulation deviation related to the repetition rate as defined below (resulting in ±0.5 telegram bit deviation).
    - For 1.5 kHz it shall be ±2.2 Hz
    - For 5 kHz it shall be ±25 Hz
    - For 15 kHz it shall be ±220 Hz
    - For 50 kHz it shall be ±2.5 kHz

5.2.3 Test Interfaces

5.2.3.1 Interface V_1

The Interface V_1 defines the data exchanged between the LTMS and the BTM functionality. This interface may require the use of a company specific Interface V_1 Adapter in order to translate the required test data to formats and timings compatible with those internal to the equipment under test.

The LTMS allows the selection of one of the following operational modes of the BTM:

- Test Mode / Normal Operation
- CW/Toggling Tele-powering Mode
- Tele-Powering on/off

After changing its operational mode, the BTM answers to any mode change request of the LTMS with its new mode status information.

The BTM or the Interface V_1 Adapter reports a periodical message that informs the LTMS about the correct operation of the BTM/LTMS link.

Upon LTMS request of Test Mode ON or after discovering an internal failure, the BTM or the Interface V_1 Adapter reports to the LTMS about its health status.

In normal conditions, during a Balise passage simulation at low speed or just after a Balise passage simulation at higher speeds, the BTM function reports the following information to the LTMS:

- BTM reporting time
- User bits extracted from the received Up-link telegram
- Balise Location data (time and/or distance)
- Overall number of non-overlapping valid telegrams received or, alternatively, the percentage of received valid telegrams
- Class of reception (i.e., with/without error correction)

More details about the Interface V_1 can be found in Annex E1 of Ref. [2].

5.2.3.2 Interface V_2

This interface may require the use of a company specific Interface V_2 Adapter in order to translate the required data to formats and timings compatible with those internal to the equipment under test.

The following data is periodically transmitted to the BTM functionality by the LTOM:

- Current distance of the On-board antenna centre from the starting point of the test session or from the last “reset” point.
- Current time since the start of the test session or since the last “reset” instant.
- Confidence level of the current time and odometer coordinates (specific use for any manufacturer).
- Current speed (real or simulated) of the On-board antenna.
- Data allowing the check of regularity and integrity of the transmitted data (Sequence Number and CRC code).

The data is transmitted every 50 ms in a serial way.

More details about the Interface V_2 can be found in Annex E2 of Ref. [2].

5.3 Test Conditions

5.3.1 General

The following general conditions should apply.

Ambient temperature	25 °C ± 10 °C
Relative humidity	25 % to 75 %
Atmospheric pressure	86 kPa to 106 kPa
Debris and metallic objects in the air-gap	None
Tele-powering mode	CW or Toggling [1]
Unintentional EMC noise within the Up-link frequency band	Negligible

In order to minimise the possible influence from the surrounding environment, there shall be a volume around the Antenna Unit under test and the air-gap transmitter loops that is free from metallic objects. The minimum extent of this volume is defined in Figure 2 below. This volume is also referred to as the "free space" condition. The 0.7 m underneath the Balise shall not include metallic objects significantly disturbing the field distribution.

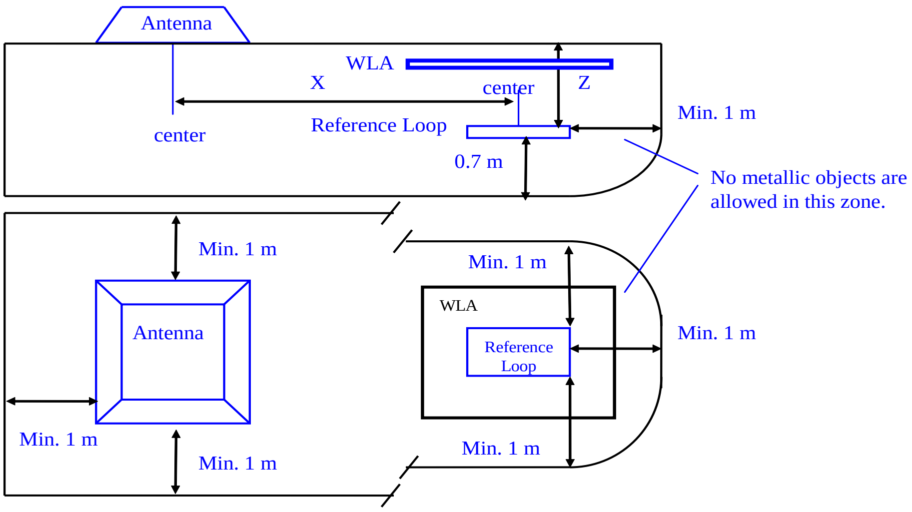


Figure 2: Definition of "free space" in the test bed

[1] Toggling only applies to On-board equipment supporting this optional mode.

5.3.2 Balise Typologies

For the purpose of testing, Reduced size Balise with transversal installation, and the specific lowest mounting conditions with respect to the Top of rails as defined in Ref. [1] shall be applied.

5.3.3 Characteristics of **the Up-link Signal**

The parameters of the 4.23 MHz FSK signal in the air gap shall be set to their nominal values. More details about terms used in this specification can be found in Ref. [1].

- f_L = 3.951 MHz ±20 kHz (frequency of the “zero” symbol)
- f_H = 4.516 MHz ±20 kHz (frequency of the “one” symbol)
- Centre Frequency = 4.234 MHz ±20 kHz
- Frequency Deviation = 282.24 kHz ±3 kHz
- Mean Data Rate = 564.48 kbits/s ±100 ppm
- Maximum Time Interval Error (MTIE2) characteristics better or equal to the limit curve of Figure 3 below.
- Amplitude jitter = less than ±1 dB

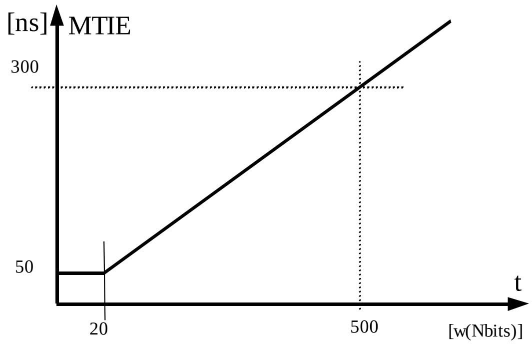


Figure 3: Nominal MTIE2 condition

5.3.4 Telegram Contents

The Reference Loop shall transmit an Up-link signal carrying a 1023 bit telegram that is valid (fulfilling the coding requirements of section. 4.3 of Ref. [1]), and which consists of 50 % ±2 % of logical “one”. The telegram shall comprise an evenly distributed run length, based upon a truncated close to exponential distribution of transitions. The Telegram 18 given in Table 24 of Ref. [2] in its finally encoded form shall be used. The user data corresponding to this encoded telegram is given in Table 22 of Ref. [2]. [2]

2 For telegram transmission, long telegram at 300 km/h presents a more difficult situation than short telegram at 500 km/h. Therefore, there will not be any worst case situations with short telegram, and consequently no need for telegram transmission tests at higher speed than 300 km/h.

5.3.5 Electrical Characteristics of the Interference

The air-gap interference signals shall be generated continuously in the air-gap either simultaneously with the dynamic Up-link signals during the transmission tests, or alone during the test of Balise Detection and On-line Transmission self-test. The interfering signal shall be constituted by a series of periodical damped oscillations as defined in Annex C.

There shall be no synchronisation between the noise pattern and the generation of Balise passages. See sections 5.2.2.4 and 5.2.2.11.

Also pure sinusoidal CW disturbance within the same frequency range as for damped oscillations shall be tested.

5.3.6 Geometrical Conditions

The geometrical reference system used for describing the position of the On-board antenna and the track-side devices is defined in section 4.5.1 of Ref. [1].

The longitudinal positions considered for the radiation diagrams of the On-board antenna can be restricted to the "main lobe zone" only, corresponding to the range from X = -500 mm to X = +500 mm.

It is the responsibility of the manufacturer of the On-board antenna to define the worst case combination(s) of height, lateral deviation, and speed based on experience from similar noise free testing according to Ref. [2]. The displacements shall take into consideration the admitted tolerances on Balise installation (specified in section 5.6 of Ref. [1]).

5.3.7 Test Speed

Simulated movement up to the maximum allowed speed shall be considered.

It is the responsibility of the manufacturer to define worst case condition(s) based on experience from testing according to Ref. [2] without simultaneous noise.

5.3.8 Metallic Objects

The test condition is defined by Annex B5.3 of Ref. [2]. The following test case shall be considered:

- Metallic Plane underneath the Balise (Annex B5.3.3).

This test case is considered the most demanding one among the different cases listed in Ref. [2]. The Antenna Unit shall be subjected to free air conditions during testing.

Please observe that the testing height shall in some cases be limited in accordance with Ref. [1].

The following applies to metallic plane underneath the Reference Loop:

- Reduced Size: Maximum test height reduced by (193 - Zb)

Please observe that the condition above is already considered when creating the basic radiation diagrams according to Ref. [2]. Consequently, the condition shall not be physically applied during the tests included herein.

5.4 Transmission Test in Presence of Air-gap Interference

5.4.1 General Description

The aim of this test is to confirm air-gap interference compatibility with an acceptable level of degradation of the data transmission reliability performance in the presence of the noise levels defined in TBD.

In presence of noise simulated in the air-gap, the following performance of the On-board transmission equipment is monitored during simulated dynamic conditions:

- The correctness of the Balise Detection reports
- The reliability level of the data reception
- The accuracy of Balise Location data
- The correctness of the sequence of the reports issued at any Balise passage

For each simulated case, the BTM function output shall be observed via the Interface V_1, and be assessed against the expected results. It is the responsibility of the manufacturer to define worst case condition(s) (vertical height, lateral deviation, and speed) based on experience from testing according to Ref. [2] without simultaneous noise.

The BTM function shall be set in the normal operational mode during testing.

The Balise Detection is considered performed correctly when a report is issued to the LTMS as a direct consequence of a Balise passage simulation, containing either the received Up-link data telegram with associated Balise location information or a simple detection report. The Balise detection function is considered failed when no report is issued within 1.3 m from the Balise passage simulation, or when an undue Balise passage report or a detection report is issued outside the area related to the Balise passage simulation.

Reliable data reception means that the "overall number of non-overlapping telegrams" reported to the LTMS after a Balise passage simulation, is sufficiently higher than the minimum number required for a reliable reception, or when the percentage of valid telegrams is exceeding a pre-determined level required for reliable reception. This minimum number is about 1.1 for long telegrams and 1.4 for short ones. An additional reliability factor (higher than 1 but lower than the margin applicable to noise free testing) may be defined by each manufacturer in order to guarantee the overall reliability target of 10^6 error-free Balise passages as described in section 4.4.4 of Ref. [1].

The Balise Location data (i.e., the time and/or distance corresponding to the Balise centre) provided by the BTM as a direct consequence of a Balise passage simulation is correct when its accuracy (evaluated against the reference data generated by the combined action of the RSG_1 and the LTOM) meets the requirements of section 4.2.10 of Ref. [1].

The criteria for the Antenna Unit - BTM function being able to correctly handle a certain sequence of Balise passage simulations are that for each simulated Balise of the sequence:

- The BTM function reports the correct telegrams with an adequate level of reception reliability
- The Balise location is reported with the required accuracy
- The reporting time requirements given in section 4.2.9 of Ref. [1] are fulfilled

The input signal to the Reference Loop generating the Up-link signal in the air-gap shall be derived from the radiation diagrams determined through static measurements in the required test conditions (according to section 5.2.3 of Ref. [2]), after their time scaling process described in section 5.2.4 of Ref. [2].

The test conditions defined in section 5.3 above shall be applied.

5.4.2 Test Configuration

The following Figure 4 defines the test geometry that applies during transmission tests in the presence of air-gap noise.

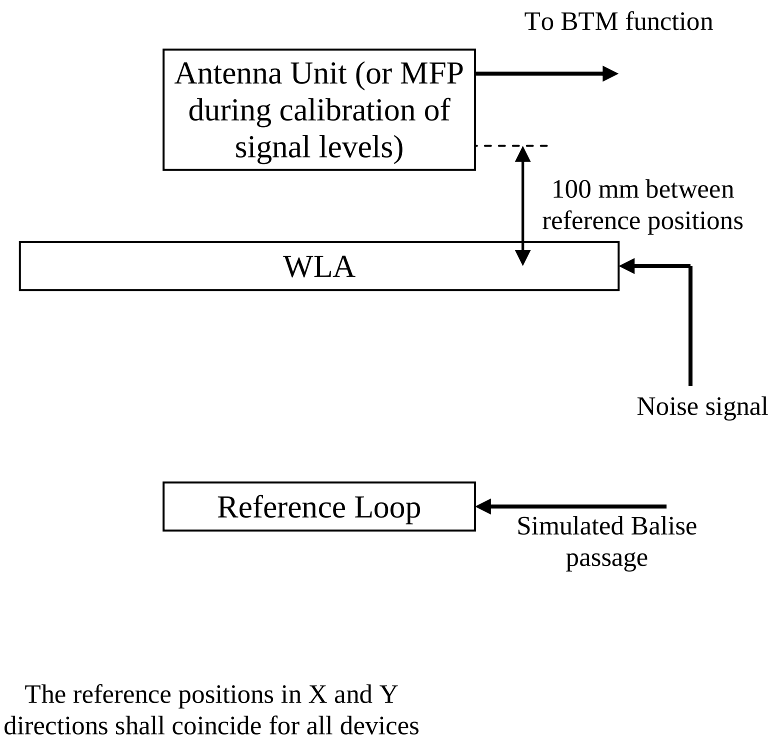


Figure 4: Geometrical Test Configuration

5.4.3 Test Procedure

The test set-up in accordance with section 5.2 above applies.

1. Position the MFP at X = 0, Y = 0, and position the WLA symmetrically in X and Y directions relative to the MFP, with its geometrical horizontal plane 100 mm below the MFP reference plane.
2. Download one interference signal pattern into the working memory of the AWG2.
3. Calibrate the level of noise through determining the relation between the field strength measured by the MFP and the current recorded by the current probe on the WLA.
4. Replace the MFP by the Antenna Unit. Please observe that the Antenna Unit reference marks shall coincide with the reference position of the previously used MFP.
5. Set the LTOM in “train motion simulation” mode with target speed set to zero.
6. Set the RSG_1 in external trigger mode.
7. Set the BTM function in “normal CW operational mode” or “Toggling mode” as prescribed by the manufacturer via an appropriate command given from the LTMS through the Interface V_1.
8. Download the Up-link signal pattern corresponding to the current test step (Balise passage simulation) into the working memory of the AWG1. This signal pattern is formed by the Up-link signal carrying the test telegram of interest and presents the required electrical characteristics. Its amplitude envelope is according to the dynamic signal pattern corresponding to the current test conditions (i.e., lateral and vertical displacements, metallic object, speed and electrical characteristics). The gain of the Power Amplifier is set in such a way to have the correct maximum current injected into the Reference Loop. An output trigger pulse (of about 100 μs duration) corresponding to the centre of the Balise passage simulation is also included in the downloaded signal pattern.
9. Set the LTOM to the target test speed and a realistic acceleration/deceleration value needed to get it from the current speed.
10. Wait until the target test speed is reached within the LTOM.
11. Download the interference signal pattern corresponding to the current test step into the working memory of the AWG2.
12. Command the AWG2 to generate the current interference signal.
13. Set the gain of the Power Amplifier in order to get the required current level injected into the WLA and check it by means of the DSO. [3]
14. Command the RSG_1 to generate the current Balise passage signal.
15. Record the reports from the BTM function received by the LTMS via the Interface V_1. At least 20 Balise passages shall be recorded.
16. Record the speed, time and position displayed by the LTOM in correspondence of the centre of the Balise passage simulations.
17. Record the time diagrams of the Up-link current injected into the Reference Loop and of the interfering current injected into the WLA during the Balise passage simulations.
18. Check that no false Balise Detection reports are issued by the BTM prior to and after the Balise passage simulations.
19. Check that the reports to the LTMS are issued not later than 100 ms after 1.3 m from the centre of the Balise passage simulations. This is done by assessment of the time stamp of the BTM report against the time/distance coordinates of the centre of the Balise passage simulation given by the LTOM.
20. Check that the correct user bits are reported by comparing the user bit contained in the Up-link signal transmitted in the air-gap and the ones included in the reports to the LTMS.
21. Check that the number of “overall number of non-overlapping telegrams” or, alternatively, the “percentage of valid telegrams”, reported to the LTMS is higher than the minimum value defined by the manufacturer for a reliable data reception.
22. Check that the correct Balise location data (distance and/or time) is reported, by comparision with the time/distance coordinates of the centre of the Balise passage simulation given by the LTOM.
23. Repeat the procedure above applying all noise signals defined in Annex C at the field strength levels defined in TBD.

[3] The required current level is the current generating the field strength specified in TBD.

6 Balise Detection and On-line Self-tests

6.1 General Description

This test is performed during simulated dynamic conditions.

The mounting conditions for the On-board antenna shall be specified by its supplier.

No debris or metallic objects shall be present during this test. No lateral displacements shall be present.

For all the non-explicitly defined conditions, the applicable test conditions defined in section 5.3 above shall be considered.

The test shall be performed with a set-up similar to the one indicated in Figure 1. The differences are that the RSG_1, the Reference Loop, and relevant cabling are removed.

The Antenna Unit shall be kept fixed in simulated motion conditions (at the fixed position X = 0) at its minimum height, with respect to the Top of Rails, as specified by the supplier.

During testing, all noise signals defined in Annex C are generated with the field strength level defined in TBD. The Interface V_1 is continuously monitored in order to acknowledge the possible issue of a BTM report signalling the failure of the on-line antenna self-test or an undue Balise detection.

The correct behaviour of the On-board equipment, in relation to the “on-line transmission self-test function”, is that no alarm is triggered in the various test steps. Alarm and related criteria are company dependent reflecting the overall system reaction. [4]

6.2 Test Configuration

The following Figure 5 defines the test geometry that applies during transmission tests in the presence of air-gap noise.

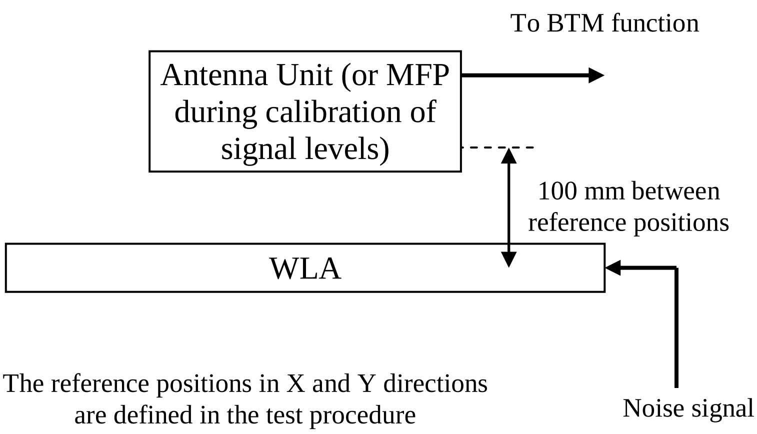


Figure 5: Geometrical Test Configuration

[4] If applicable, the applied criteria shall be declared in the test report.

6.3 Test Procedure

The test set-up in accordance with section 5.2 above applies, with the removal of the RSG-1, the Reference Loop, and the related cabling. The Antenna under test is kept fixed in the centre of the test bed at its minimum height.

1. Position the MFP at X = 0, Y = 0, and at the minimum height defined by the Antenna Unit supplier, and position the WLA symmetrically in X and Y directions relative to the MFP, with its geometrical horizontal plane 100 mm below the MFP reference plane.
2. Download one interference signal pattern into the working memory of the AWG2.
3. Calibrate the level of noise through determining the relation between the field strength measured by the MFP and the current recorded by the current probe on the WLA.
4. Replace the MFP by the Antenna Unit. Please observe that the Antenna Unit reference marks shall coincide with the reference position of the previously used MFP.
5. Set the LTOM in “simulated movement” mode with initial speed set to zero.
6. Set the BTM function in “normal CW operational mode” or “Toggling mode” as prescribed by the manufacturer via an appropriate command given from the LTMS through the Interface V_1.
7. Download the interference signal pattern corresponding to the current test step into the working memory of the AWG2.
8. Command the AWG2 to generate the applicable interference signal.
9. Simulate the movement of the antenna, via the LTOM from 0 km/h up to the actual test speed.
10. Set the gain of the Power Amplifier in order to get the required current level injected into the WLA and check it by means of the DSO [5]. Maintain noise generation for 50 s. Confirm that there is no undue Balise detection or antenna failure report.
11. Switch off noise generation and simulate the movement of the antenna back to 0 km/h again, considering the supplier specific maximum train deceleration (if any).
12. Repeat the procedure above applying all noise signals defined in Annex C at the field strength levels defined in TBD.

[5] The required current level is the current generating the field strength specified in TBD.

Annex A (Normative), Wide Loop Antenna (WLA)

A1 Characteristics

In a volume limited by Δx = Δy = ±200 mm and Δz = ±100 mm from the geometrical centre of the loop, the following characteristics apply:

- Amplitude variation of the H-field within the volume is less than ±1 dB for the frequency range 1 MHz to 10 MHz.
- E-field attenuation is better than 20 dB for the in-band frequency range 4.23 MHz ±0.5 MHz.
- E-field attenuation is better than 12 dB for the out-band frequency range 1 MHz to 10 MHz (excluding the 4.23 MHz ±0.5 MHz range).

A2 Design of the WLA

A2.1 Mechanical Dimensions and Construction

Figure 6 shows the geometrical construction of the WLA (Wide Loop Antenna) and the feeding circuit. The tube diameter shall be D2 = 12 mm, and the thickness of the wall shall be 1 mm. The length a, and the width b shall both be 1.2 m. The loop shall be made of copper. The BICP (Bulk Injection Current Probe) could be any commercial product suitable with the intended design (e.g. TEGAM 95236-1 or similar) and the CP (Current Probe) could be any commercial product suitable with the intended design (e.g. TEGAM 91550 or similar).

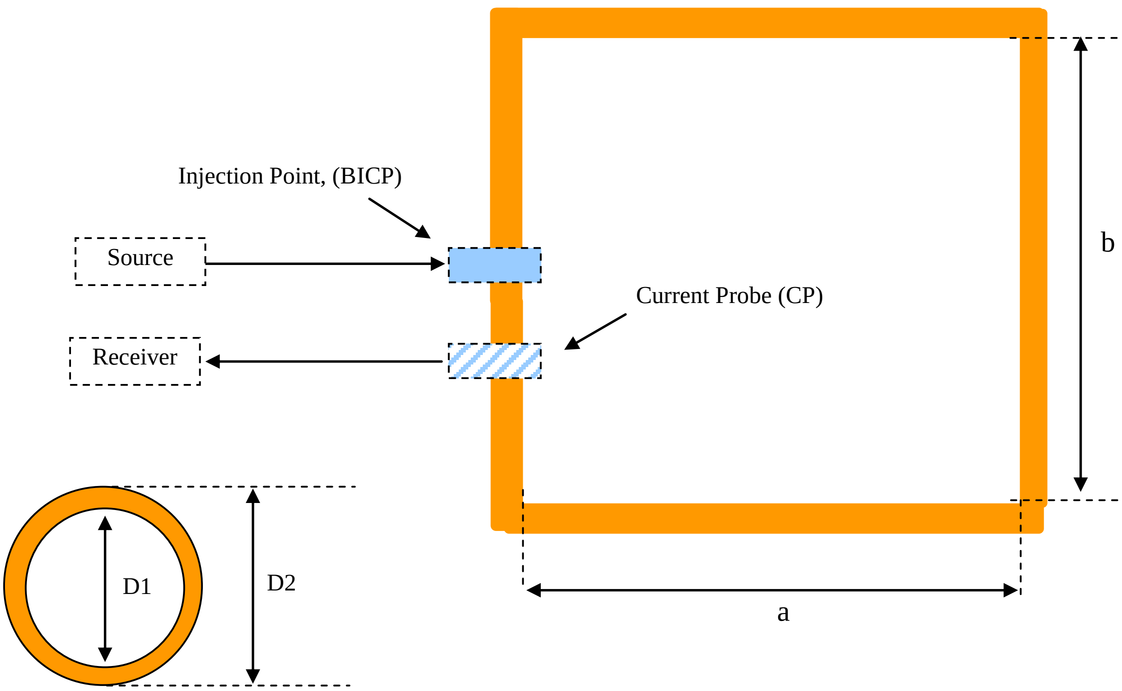


Figure 6: Geometrical layout

To use the antenna over a wide range, a BICP (Bulk Injection Current Probe) is recommended for symmetrical aspects, but this is not a part of the antenna itself. With this injection method the unsymmetrical effects can be reduced to a minimum.

When using the antenna in the region of 4.23 MHz, an antenna current of 1.33 mA will generate a magnetic field strength of 1 mA/m within the volume defined in chapter A1. A current of 13 A_{RMS} inside the antenna will generate a magnetic field strength of 10 A_{RMS}/m or 140 dBμA/m. The corresponding effective magnetic flux density is 12.6 μT.

Figure 7: Parts to be mounted

Figure 8: Entire antenna construction

A2.2 Signal Injection of the WLA

The Bulk Injection Current Probe provides one feasible way of applying a controlled RF interference level to an EUT (Equipment Under Test). The BICP is simply clamped around the WLA, which becomes a one turn secondary winding, with the current probe forming the core primary winding of an RF transformer. The Bulk Injection Current Probe is specifically designed to provide minimum insertion loss over the frequency range up to 10 MHz.

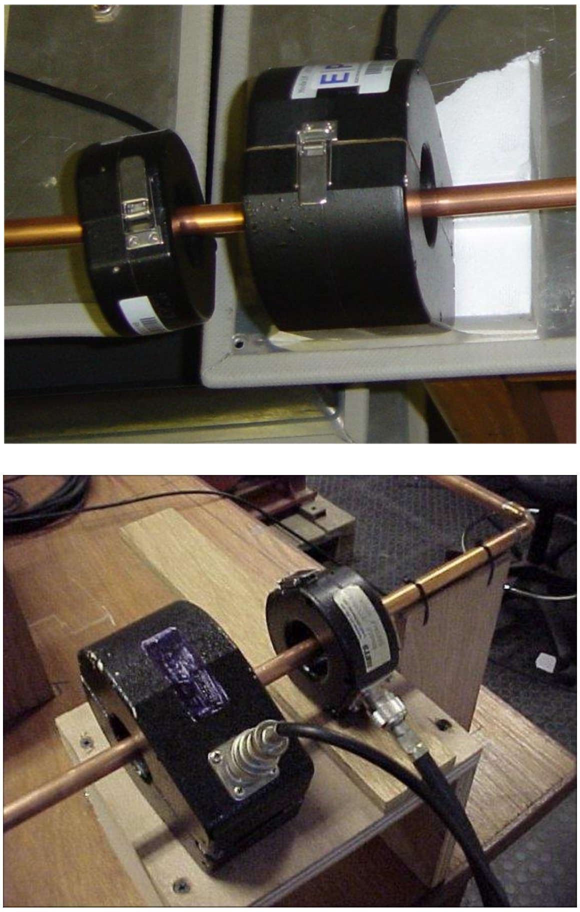


Figure 9: Feeding point with the BICP and CP

A3 Antenna Calibration and Antenna Factor

A3.1 General

The purpose of the WLA calibration is to ensure that the relation of the input current to the generated magnetic field strength is defined. During the succeeding measurements, the current shall be kept constant in the presence of the test object in order to maintain the calibrated magnetic field strength.

The WLA and the cables that have been used to establish the calibrated magnetic field strength shall be used for the testing.

Since it is impossible to establish a uniform calibration field close to an earth reference plane, the geometrical calibration volume is established at a height no closer than 0.8 m above the earth reference plane.

A3.2 Theory

It can be theoretically proven that a current of 1 mA_{RMS} or 60 dBµA generates field strength at geometrical centre of the WLA of 750 µA/m or 57.5 dBµA/m.

A3.3 Practical Verification

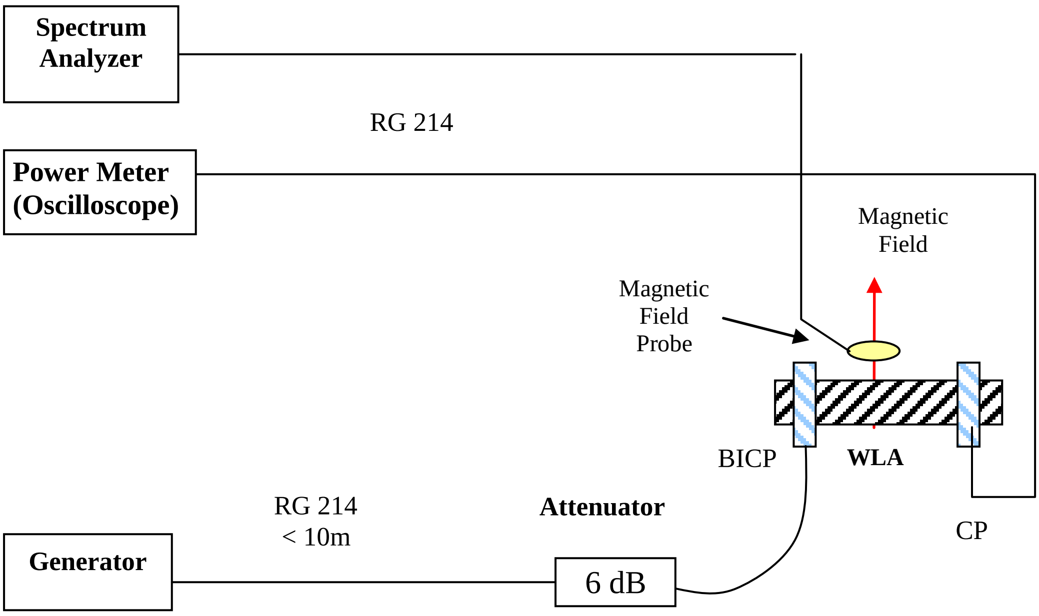


Figure 10: Measurement set-up

The Magnetic field Probe is defined in Annex B herein.

All cabling should be de-bugged using suitable ferrite cores.

Procedure:

1. Set the frequency of the generator to 4.23 MHz and the output power to 0 dBm.
2. Adjust the injected current to 1.33 mA_{RMS} (observed with the current probe CP).
3. Measure the value of the resulting magnetic field using the magnetic field probe and the spectrum analyser.
4. Consider the calibration factor of the magnetic field probe.

Annex B (Normative), Magnetic Field Probe (MFP)

B1 Performance Data

The following performance data for the MFP in the absence of the screen plate is required.

Frequency Range (where the conversion factor is within the below-specified limits).	1 MHz – 10 MHz
Conversion factor within the 1 MHz to 10 MHz range (exact value by calibration) H/V.	Nominally 1.1 A/Vm
Conversion factor flatness within the 1 MHz to 10 MHz frequency range.	+5 dB / -1 dB [6]
Calibration Accuracy at calibration frequency.	± 0.5 dB
Conversion factor flatness within the 4.23 MHz ±1 MHz frequency range.	± 0.5 dB
Amplitude Linearity (within the relevant dynamic range).	± 0.1 dB
Active probe area.	200 mm x 200 mm

B2 Overall Design

General

The overall mechanical configuration is shown in Figure 11 at the end of this annex.

Because of its exposure to the environment if used underneath a vehicle, there is a need to protect the antenna from water spray and other things. This protection is not included herein.

Screen Plate

The screen plate, 400 mm × 400 mm, shall be made of aluminium 4 mm thick. This screen plate is intended for creating a predictable environment.

Holders

The holders shall be made of plastic material (polyvinyl chloride) with a diameter of 25 mm. The length of the holders shall be such that the centre of the antenna loop is positioned 75 mm underneath the screen plate.

[6] The actual conversion factor versus frequency obtained during characterisation shall be considered during measurements.

Loop

The loop shall be according to the Modified Test Antenna (in accordance with section H3.3 in Ref. [2]). The cross-section of the loop shall be ϕ 2.5 mm with inner radius of the corners of 5 mm, and the material shall be solid brass or copper.

4.23 MHz Transformer

The 4.23 MHz transformer shall consist of the core and two windings with a ratio of 2:7, where the primary winding (2 turns) is an extension of the loop itself. Recommended core is Philips type RCC 16/9.6/6.3, material 4A11 ("Philips pink").

The core shall be rigorously shielded with the shield connected to the coaxial ground of the output cable.

Balun

The Balun shall be the General Purpose Balun according to section H5.2 in Ref. [2].

B3 Calibration

Introduction

The calibration of the loop elements shall be performed using the reciprocal theorem in combination with field conformity measurements using two identical loops. The measured attenuation shall be compared with the theoretical attenuation between two loops positioned in a number of different representative positions relative to each other. The conformity with the theoretical results confirms that the size and the shape of the loops are the same as the theoretical (within certain tolerance). It is possible to determine the attenuation of the electrical network between the (theoretically calculated) loop and the connector of the loop. The magnetic field (H) is determined by the inductive law dividing the flux with the theoretical area of the loop and the permeability of the vacuum. The deviations between the individual loops shall be measured by repeating the measurement involving at least three loops calibrated pair by pair, and involving all combinations.

The reason for the choice of this procedure is the known problem (with other procedures) to create homogeneous field with sufficient field strength and accuracy at this frequency, and to be able to perform the calibration with sufficient accuracy. This procedure facilitates determining the field conversion factor in the inhomogeneous field created by a loop of the same kind.

Field Conformity Requirements and Nominal Mutual Inductance

Calibration of the conversion factor of an individual loop shall be performed by measuring the attenuation between the defined output connector of the loop, to the output connector of another loop of the same design. The environment shall constitute free air conditions within a minimum zone of 0.7 m from any of the involved loops. Some support might be closer if the extent of the area perpendicular to the magnetic field can be judged small. The measurement shall be repeated for all defined test points (i.e., the geometrical difference in co-ordinates of the reference mark of one loop to the reference mark of the other loop), and for all combinations of the three loops of the same design. Table 1 below gives the theoretical mutual inductance between the two loops at the various positions.

X [mm]	Y [mm]	Z [mm]	M [nH]	X [mm]	Y [mm]	Z [mm]	M [nH]
-100	-100	100	21.33	-100	100	200	10.71
100	-100	100	21.33	100	100	200	10.71
0	0	100	64.46	-100	-100	300	5.52
-100	100	100	21.33	100	-100	300	5.52
100	100	100	21.33	0	0	300	8.25
-100	-100	200	10.71	-100	100	300	5.52
100	-100	200	10.71	100	100	300	5.52
0	0	200	20.24				

Table 1: Theoretical mutual inductance

Please observe that the above applies to unshielded loops. Section 0 defines how to achieve the compensation applicable to the presence of the screen plate.

Conversion Factor

Calculation of conversion factor from measurements of the attenuation is presented in this section.

The conversion factor can be determined by the equation:

Conversion Factor^2 = 2 M / ((A μ_o)^2 ω Z_o MeasuredAttenuation)

where

- **M** is the theoretical mutual inductance between the nominal loops at the actual relative position.
- **A** is the nominal Area of the loops.
- **μ_o** is the permeability of vacuum.
- **ω** is the angular frequency used at the calibration measurement.
- **Z_o** is the nominal impedance of the measurement of S21.
- **MeasuredAttenuation** is the measured S21 at the loop connector with 50 Ω nominal impedance at the actual relative position.

The expression is derived from following equations:

Conversion Factor = Ua / (A ω μ_o U2)

Ua = 2 U1 Ga ω M

U2 = Ua Ga Z_o

MeasuredAttenuation = U2/U1

where

- **U1** is the voltage measured over 50 Ω load impedance connected to the ideal generator source with 50 Ω source impedance.
- **U2** is the voltage measured over a 50 Ω load at the second (receiver) loop.
- **Ua** is the voltage induced over the second loop from the first loop (the induction due to the resulting current in the loop itself is not regarded belonging to this voltage).
- **Ga** is the trance conductance between the voltage source (**2*U1**) and the antenna loop current (disregarding the induction into the first loop from the second loop, and that the theoretical source impedance is included in the "Ga network")

The reciprocal theorem gives that the trance conductance between the induced voltage of the second loop and the current in the 50 Ω load at the connector is also **Ga.**

Three loops are to be involved in a set of calibration. The mean value (over all tested points) of each individual calibration is called CF12, CF13 and CF 23 respectively. The numbers indicate the involved loops (1, 2 and 3). The calibration factor valid for each loop is called CF1, CF2 and CF3 respectively.

- CF1= CF12 + CF13 - CF23
- CF2 = CF12 - CF13 + CF23
- CF3 = -CF12 + CF13 + CF23

Application for Conversion Factor Determination

The herein included embedded object constitutes an Excel application that is to be used for the purpose of evaluating the conversion factor of the MFP.

Instructions for use of the applications are included in the Excel chart.

For informative purposes, the hereafter following figures includes bitmap pictures of the charts of the embedded objects.

Please observe that both the bitmaps and the embedded objects are filled with fictitious data (included in the yellow cells).

FieldProbeVer.xlsx

Loop 2 & 1, 0 deg Positioning parameters			Calculated mutual impedance		Measured attenuation				Conversion Factor (C.F.) per point			
Long., x [mm]	Lateral y [mm]	Height, z [mm]	[dBnH]		1 MHz [dB]	2.5 MHz [dB]	4.25 MHz [dB]	6 MHz [dB]	1 MHz [dBA/Vm]	2.5 MHz [dBA/Vm]	4.25 MHz [dBA/Vm]	6 MHz [dBA/Vm]
									1000000	2500000	4250000	6000000
-100	-100	100	26.58		-29.97	-36.12	-40.39	-43.39	2.29	1.38	1.21	1.22
100	-100	100	26.58		-29.43	-35.73	-39.89	-42.89	2.02	1.19	0.97	0.97
0	0	100	36.19		-20.48	-26.63	-30.76	-33.76	2.35	1.44	1.20	1.20
-100	100	100	26.58		-29.98	-36.34	-40.42	-43.42	2.29	1.49	1.23	1.23
100	100	100	26.58		-29.78	-36.00	-40.09	-43.09	2.19	1.32	1.07	1.07
-100	-100	200	20.59		-35.99	-42.21	-46.28	-49.28	2.30	1.43	1.17	1.17
100	-100	200	20.59		-35.45	-41.97	-46.18	-49.18	2.03	1.31	1.11	1.12
0	0	200	26.13		-30.66	-36.71	-40.89	-43.89	2.41	1.45	1.24	1.24
-100	100	200	20.59		-35.75	-42.19	-46.28	-49.28	2.19	1.42	1.17	1.17
100	100	200	20.59		-35.80	-42.05	-46.08	-49.08	2.21	1.36	1.07	1.07
-100	-100	300	14.83		-42.48	-48.31	-52.04	-55.04	2.67	1.60	1.17	1.17
100	-100	300	14.83		-41.30	-47.69	-51.95	-54.95	2.08	1.29	1.12	1.12
0	0	300	18.33		-38.25	-44.42	-48.91	-51.91	2.30	1.41	1.35	1.35
-100	100	300	14.83		-41.55	-48.09	-51.98	-54.98	2.21	1.49	1.14	1.14
100	100	300	14.83		-41.17	-47.77	-51.98	-54.98	2.02	1.34	1.14	1.14
							Std. dev:		0.17	0.10	0.09	0.09
							Average		2.24	1.40	1.16	1.16

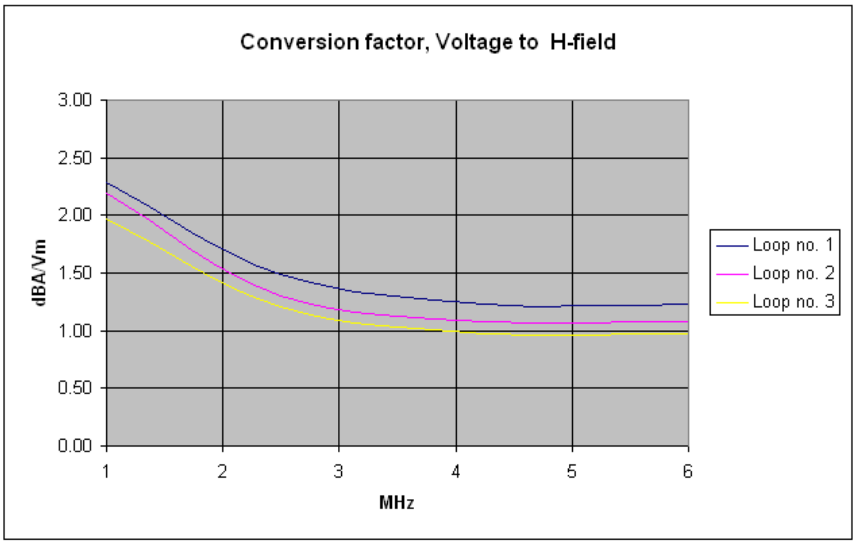
Loop 1 & 3, 0 deg Positioning parameters			Calculated mutual impedance		Measured attenuation				Conversion Factor per point			
Long., x [mm]	Lateral y [mm]	Height, z [mm]	[dBnH]		1 MHz [dB]	2.5 MHz [dB]	4.25 MHz [dB]	6 MHz [dB]	1 MHz [dBA/Vm]	2.5 MHz [dBA/Vm]	4.25 MHz [dBA/Vm]	6 MHz [dBA/Vm]
									1000000	2500000	4250000	6000000
-100	-100	100	26.58		-29.83	-36.02	-40.13	-43.13	2.22	1.33	1.08	1.09
100	-100	100	26.58		-29.14	-35.65	-39.85	-42.85	1.87	1.15	0.94	0.94
0	0	100	36.19		-20.13	-26.46	-30.64	-33.64	2.17	1.36	1.14	1.14
-100	100	100	26.58		-29.78	-36.15	-40.40	-43.40	2.19	1.40	1.22	1.22
100	100	100	26.58		-29.56	-35.81	-39.98	-42.98	2.08	1.23	1.01	1.01
-100	-100	200	20.59		-35.78	-42.11	-45.99	-48.99	2.20	1.38	1.02	1.02
100	-100	200	20.59		-35.42	-41.83	-45.89	-48.89	2.02	1.24	0.97	0.97
0	0	200	26.13		-30.16	-36.57	-40.73	-43.73	2.16	1.38	1.16	1.16
-100	100	200	20.59		-35.53	-42.05	-46.22	-49.22	2.07	1.35	1.14	1.14
100	100	200	20.59		-35.79	-41.98	-46.04	-49.04	2.20	1.32	1.05	1.05
-100	-100	300	14.83		-42.14	-48.05	-51.83	-54.83	2.50	1.48	1.06	1.06
100	-100	300	14.83		-41.14	-47.84	-51.91	-54.91	2.00	1.37	1.10	1.10
0	0	300	18.33		-38.10	-44.27	-48.69	-51.69	2.23	1.33	1.24	1.24
-100	100	300	14.83		-40.99	-48.01	-51.79	-54.79	1.93	1.46	1.04	1.04
100	100	300	14.83		-41.32	-47.93	-52.44	-55.44	2.09	1.42	1.37	1.37
							Std. dev:		0.15	0.09	0.11	0.11
							Average		2.13	1.35	1.10	1.10

Loop 3 & 2, 0 deg Positioning parameters			Calculated mutual impedance		Measured attenuation				Conversion Factor per point			
Long., x [mm]	Lateral y [mm]	Height, z [mm]	[dBnH]		1 MHz [dB]	2.5 MHz [dB]	4.25 MHz [dB]	6 MHz [dB]	1 MHz [dBA/Vm]	2.5 MHz [dBA/Vm]	4.25 MHz [dBA/Vm]	6 MHz [dBA/Vm]
									1000000	2500000	4250000	6000000
-100	-100	100	26.58		-29.54	-35.85	-39.95	-42.95	2.07	1.25	0.99	1.00
100	-100	100	26.58		-29.42	-35.60	-39.88	-42.88	2.01	1.12	0.96	0.96
0	0	100	36.19		-19.94	-26.32	-30.47	-33.47	2.08	1.29	1.06	1.06
-100	100	100	26.58		-29.66	-35.94	-40.08	-43.08	2.13	1.29	1.06	1.06
100	100	100	26.58		-29.53	-35.83	-40.04	-43.04	2.07	1.24	1.04	1.04
-100	-100	200	20.59		-35.93	-42.02	-46.12	-49.12	2.27	1.34	1.09	1.09
100	-100	200	20.59		-35.05	-41.61	-45.96	-48.96	1.83	1.13	1.00	1.01
0	0	200	26.13		-29.90	-36.39	-40.52	-43.52	2.03	1.29	1.05	1.06
-100	100	200	20.59		-35.61	-41.92	-45.82	-48.82	2.11	1.29	0.94	0.94
100	100	200	20.59		-35.57	-41.82	-46.06	-49.06	2.10	1.24	1.05	1.06
-100	-100	300	14.83		-41.50	-47.59	-51.92	-54.92	2.18	1.24	1.11	1.11
100	-100	300	14.83		-40.42	-47.54	-51.27	-54.27	1.64	1.22	0.78	0.78
0	0	300	18.33		-38.09	-44.19	-48.47	-51.47	2.22	1.29	1.13	1.13
-100	100	300	14.83		-41.91	-47.70	-51.89	-54.89	2.39	1.30	1.09	1.09
100	100	300	14.83		-41.21	-47.63	-51.84	-54.84	2.03	1.26	1.07	1.07
							Std. dev:		0.18	0.06	0.09	0.09
							Average		2.08	1.25	1.03	1.03

Report of calibrated result (CF and measured SDEV):

In this analyses the CF is calculated for each individual point and individual Loop. This makes it possible to directly evaluate statistics (Average, SDEV ,Max and Min) based on the result of individual points.

Positioning parameters			Conversion Factor											
Long., x [mm]	Lateral y [mm]	Height, z [mm]	Loop1, 1 MHz [dBA/Vm]	Loop1, 2.5 MHz [dBA/Vm]	Loop1, 4.25 MHz [dBA/Vm]	Loop1, 6 MHz [dBA/Vm]	Loop2, 1 MHz [dBA/Vm]	Loop2, 2.5 MHz [dBA/Vm]	Loop2, 4.25 MHz [dBA/Vm]	Loop2, 6 MHz [dBA/Vm]	Loop3, 1 MHz [dBA/Vm]	Loop3, 2.5 MHz [dBA/Vm]	Loop3, 4.25 MHz [dBA/Vm]	Loop3, 6 MHz [dBA/Vm]
-100	-100	100	2.43	1.47	1.30	1.31	2.14	1.30	1.12	1.12	2.00	1.20	0.87	0.87
100	-100	100	1.88	1.21	0.95	0.95	2.16	1.17	0.98	0.99	1.87	1.08	0.93	0.94
0	0	100	2.44	1.51	1.28	1.29	2.25	1.37	1.12	1.12	1.90	1.20	1.00	1.00
-100	100	100	2.35	1.60	1.39	1.39	2.23	1.39	1.06	1.07	2.04	1.19	1.05	1.05
100	100	100	2.21	1.31	1.04	1.04	2.18	1.33	1.10	1.10	1.96	1.14	0.98	0.98
-100	-100	200	2.23	1.48	1.10	1.10	2.38	1.39	1.24	1.24	2.17	1.29	0.94	0.94
100	-100	200	2.22	1.42	1.08	1.08	1.85	1.21	1.15	1.15	1.82	1.06	0.86	0.86
0	0	200	2.53	1.55	1.34	1.34	2.28	1.36	1.14	1.14	1.78	1.22	0.97	0.98
-100	100	200	2.14	1.49	1.36	1.37	2.23	1.36	0.97	0.97	2.00	1.22	0.91	0.91
100	100	200	2.32	1.43	1.06	1.06	2.10	1.28	1.08	1.08	2.09	1.20	1.03	1.03
-100	-100	300	2.99	1.84	1.12	1.12	2.35	1.37	1.21	1.22	2.01	1.11	1.00	1.00
100	-100	300	2.44	1.44	1.44	1.44	1.72	1.14	0.80	0.80	1.56	1.29	0.76	0.76
0	0	300	2.31	1.45	1.46	1.46	2.30	1.37	1.24	1.24	2.15	1.22	1.02	1.02
-100	100	300	1.75	1.65	1.09	1.09	2.66	1.34	1.18	1.19	2.11	1.26	1.00	1.00
100	100	300	2.07	1.49	1.44	1.44	1.96	1.18	0.84	0.84	2.11	1.35	1.30	1.30
	Std. dev:		0.29	0.14	0.17	0.17	0.23	0.09	0.13	0.13	0.16	0.08	0.12	0.12
	Average		2.29	1.49	1.23	1.23	2.19	1.30	1.08	1.08	1.97	1.20	0.97	0.98



Compensation for Presence of the Screen Plate

In order to compensate the conversion factor for the presence of the screen plate, the following procedure shall be applied:

1. Position one MFP loop without any screen plate concentrically with respect to the WLA reference point at a vertical distance of 100 mm above the reference point of the WLA.
2. Using a network analyser, measure the attenuation (in dB) between the MFP loop and the WLA at the frequency 4.25 MHz. Record the measured attenuation.
3. Apply the screen plate to the MFP loop.
4. Repeat step 2. Please observe that the relative positioning between reference points of the MFP loop and WLA shall be maintained.
5. The compensation for the conversion factor is obtained as the difference (in dB) between the recordings in steps 2 and 4.

B4 Outline Drawing

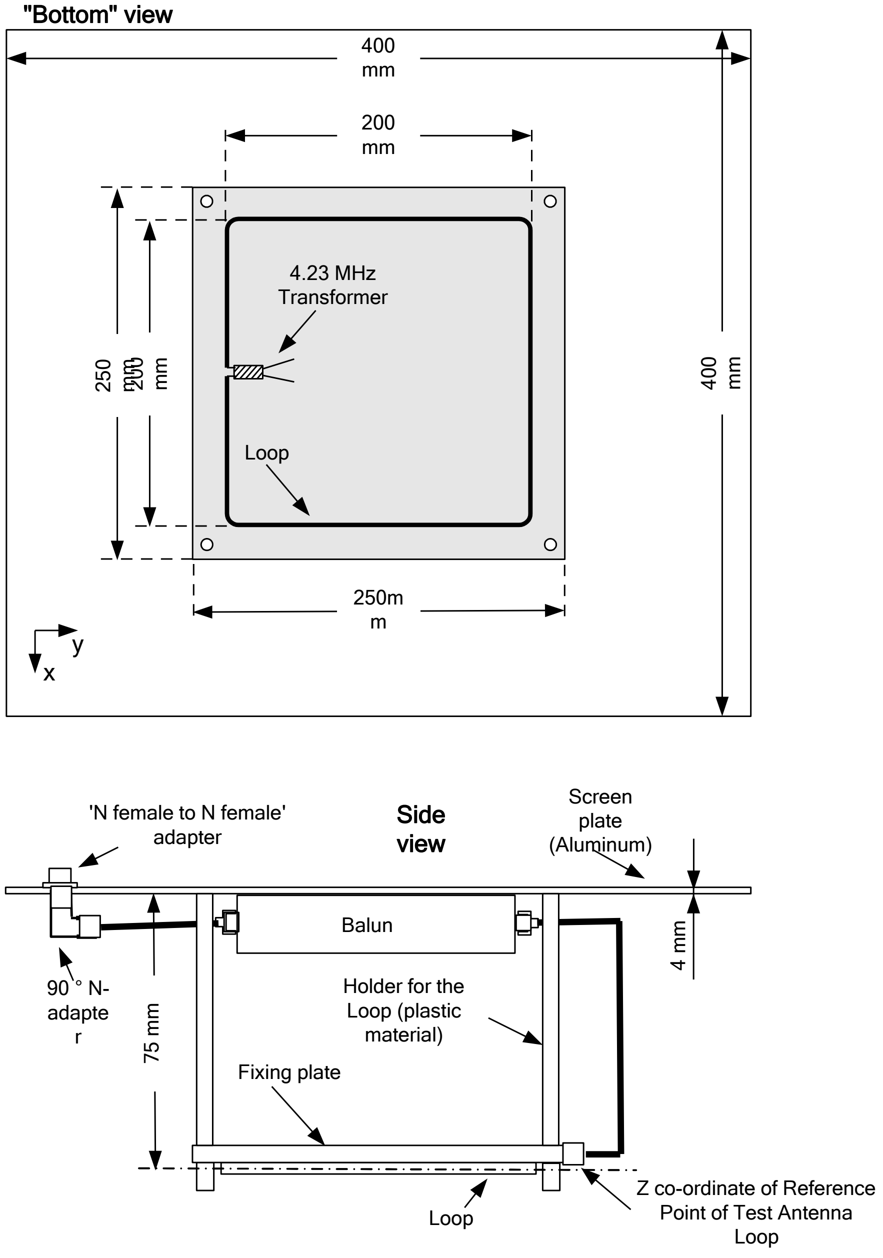


Figure 11: Physical description of the Measuring Antenna principles

Annex C (Normative), Test Signals

C1 General

Test signals shall consist of damped oscillations as illustrated in Figure 12 below.

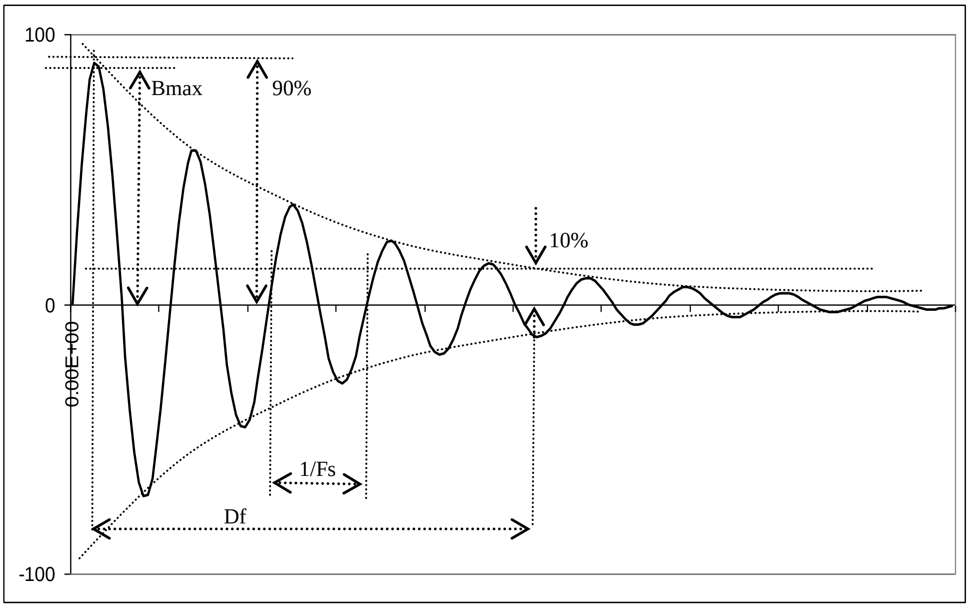


Figure 12: Shape of the Damped Sinusoidal Interference Signal

The disturbance signals shall not be synchronised with the Up-link signal.

The phase of the damped sinusoidal signal shall be suitably tuned in order to achieve a DC free signal (already performed in the test pattern file of section C2.5).

Also pure siniusoidal CW disturbance shall be applied.

C2 Applicable Parameters

C2.1 General

The following sections define the applicable values for the following parameters shown in Figure 12.

- Self Frequency, Fs
- Decaying Factor, Df
- Repetition Rate

C2.2 Self Frequency

The following self frequencies shall be used:

- 1.0 MHz
- 2.5 MHz
- 3.9 MHz
- 4.5 MHz
- 6.0 MHz

The frequencies above apply also for pure siniusoidal CW disturbance.

C2.3 Decaying Factor

The following decaying factors shall be used:

- Five cycles
- Thirty cycles

C2.4 Repetition Rate

The following repetition rates shall be used:

- 1.5 kHz
- 5 kHz
- 15 kHz

C2.5 Test Patterns

The following test patterns for damped sinusoidal oscillations shall be used:

Test_patterns.xlsx

Annex D (Informative), Intentionally Deleted

Annex E (Informative), Low Pass and Band Pass Filters

E1 General

The Low Pass filters shown in the test set-up of Figure 1 have the basic objective of filtering out the power signal at 27 MHz collected by the WLA and by the Reference Loop. This is needed to prevent the 27 MHz energy to reach the RSG/NSG Power amplifiers.

Such filters should present attenuation higher than 60 dB at 27.095 MHz and at its higher level harmonics.

They shall not introduce appreciable alteration of the basic characteristics required for the test signals. This means:

- Band-pass sufficiently higher than the signal band. A band-pass of DC to10 MHz is recommended.
- Average attenuation lower than 0.3 dB within the full band-pass and attenuation variations lower than 0.1 dB within the band 3 MHz to 6 MHz.
- Group delay variation lower than 100 ns within the full band-pass, and lower than 10 ns within the band 33 MHz to 6 MHz.
- Input and output impedance of (50 ±j1) Ω at both terminals, when the opposite terminal is closed with a resistive 50 Ω load.

The two filters shall be able to handle a maximum continuous power of 50 W at 27.095 MHz entering into one terminal and a pulsed power of about 100 W at DC to10 MHz into the other terminal. The pulsed power can last some hundreds of milliseconds with a repetition period of few seconds

The following figures show an example of filter proposed for use.

E2 Low Pass Filter

E2.1 Design Solution

A Butterworth-type filter has been chosen for the basic needs of minimising the delay group variation within the bandwidth. The ninth order has been chosen for maximising the attenuation at 27 MHz.

The following Figure 13 gives the schematic diagram of the filter and the value of each component. The inductors, rated at a maximum current of 5 A, have to be manufactured on purposes. The capacitors, rated at a maximum voltage of 200 Vrms, have to be obtained by parallel combination of commercially available components.

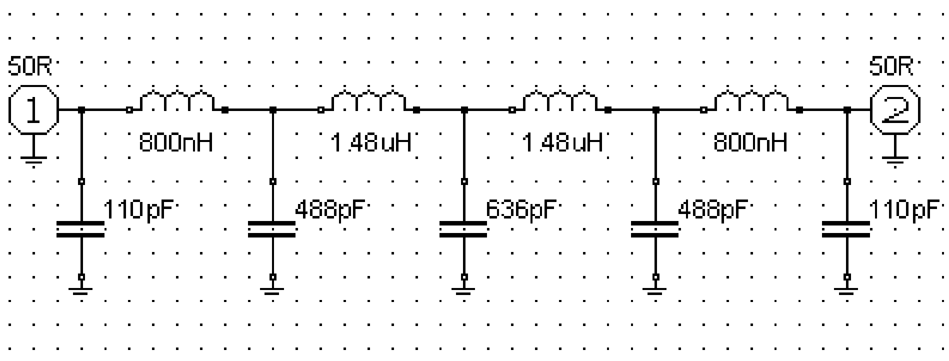


Figure 13: Low Pass 9th order Butterworth filter

E2.2 Simulation Results

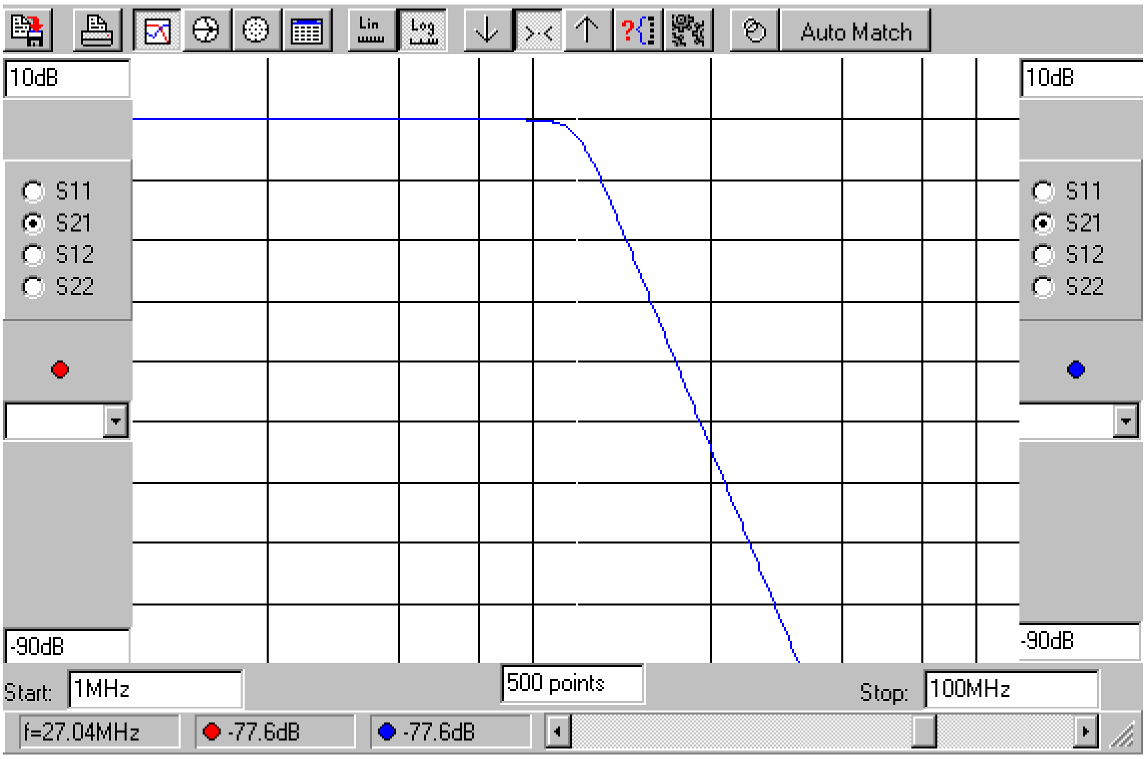


Figure 14: Filter attenuation (S21) in the band 1 MHz to 100 MHz

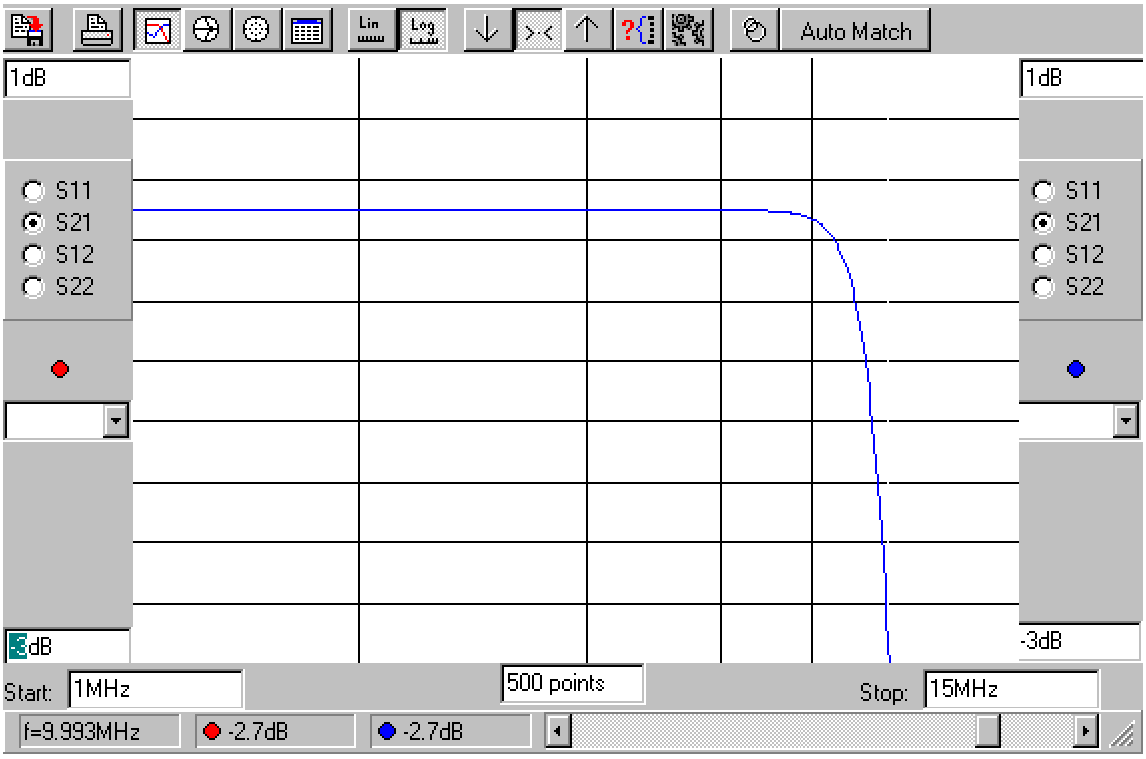


Figure 15: Filter attenuation (Zoom)

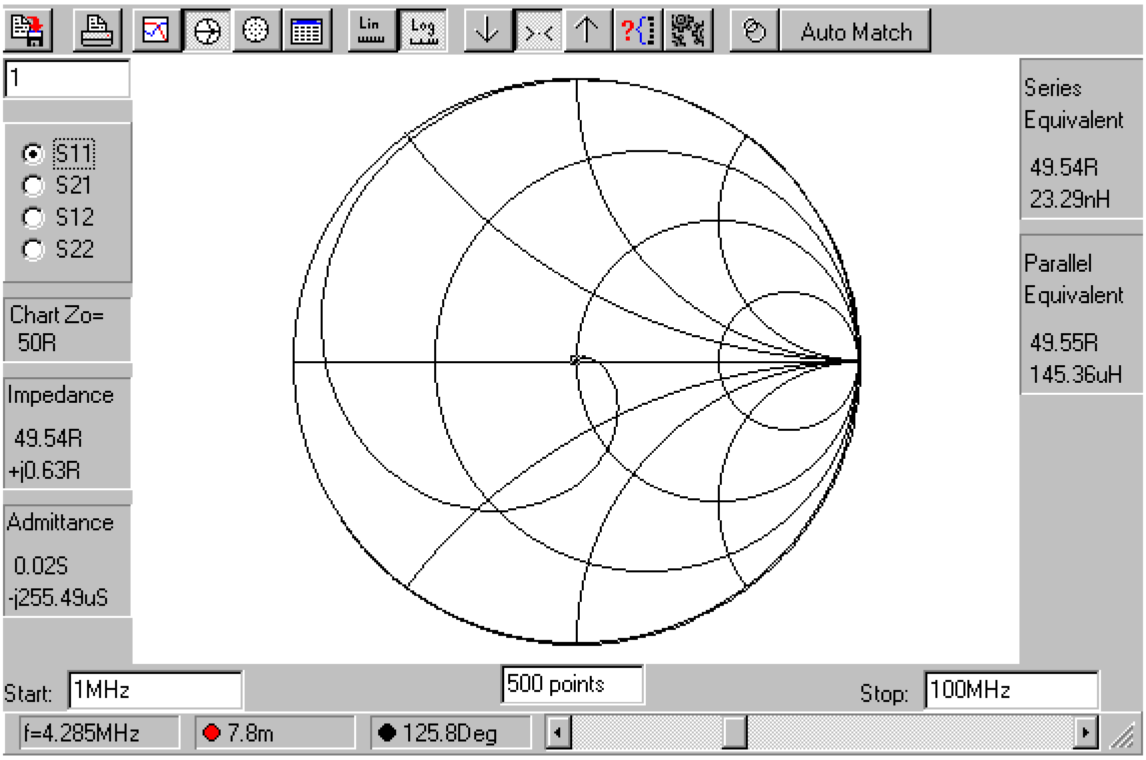


Figure 16: Input Impedance (S11) in the range 1 MHz to 100 MHz

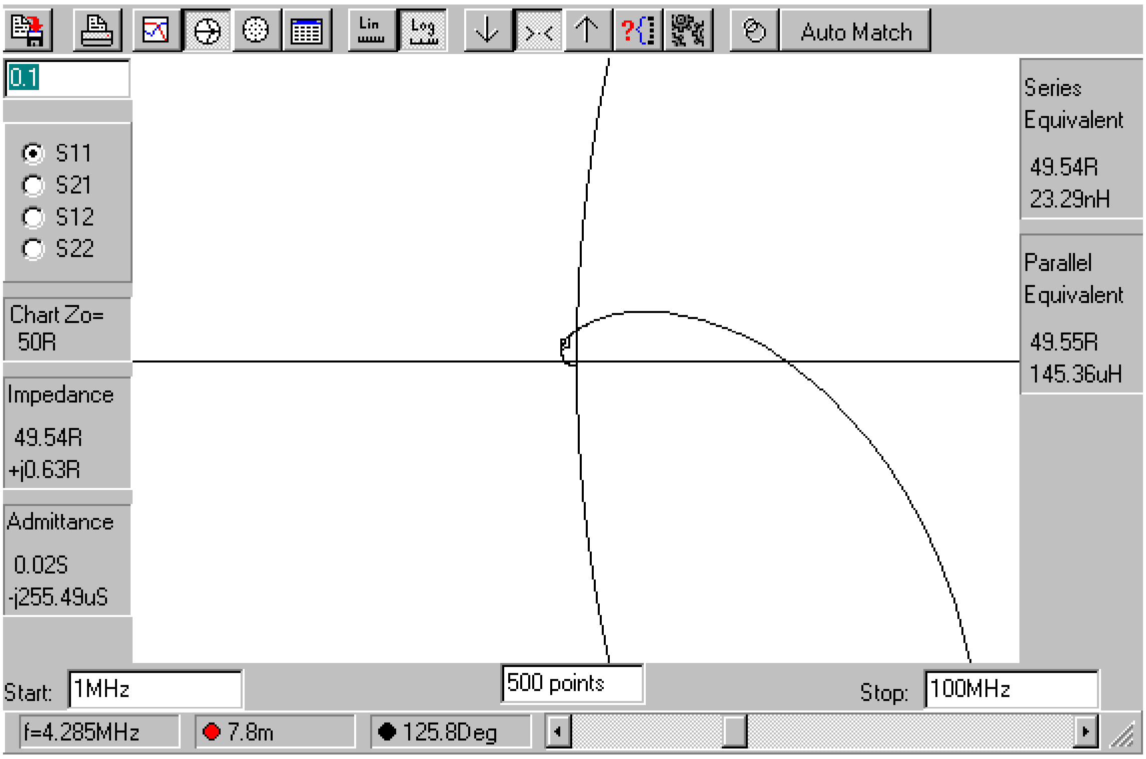


Figure 17: Input Impedance (zoom)

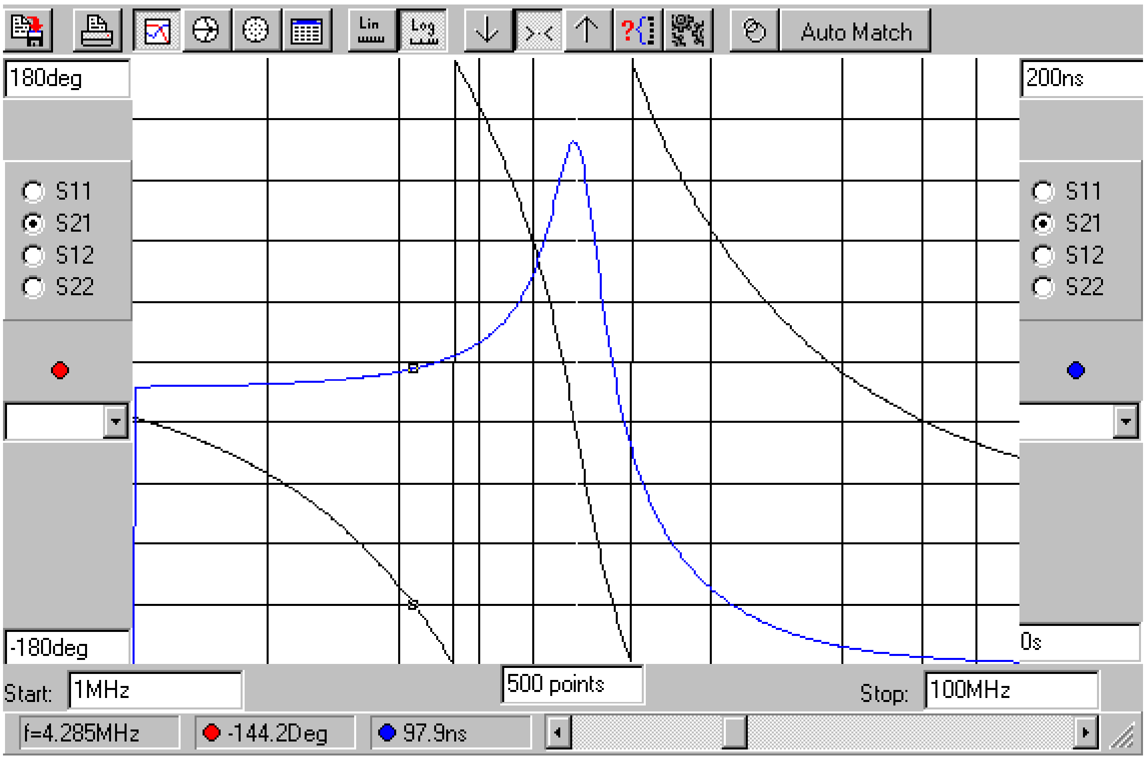


Figure 18: Group delay and phase in the range 1 MHz to 100 MHz

E3 Narrow Band Filter in the Up-link Band

E3.1 Design Solution

A Butterworth-type filter has been chosen for the basic needs of minimising the delay group variation within the bandwidth. The seventh order has been chosen as a trade off between circuit complexity and maximisation of out-band attenuation.

The following Figure 19 gives the schematic diagram of the filter and the value of each component.

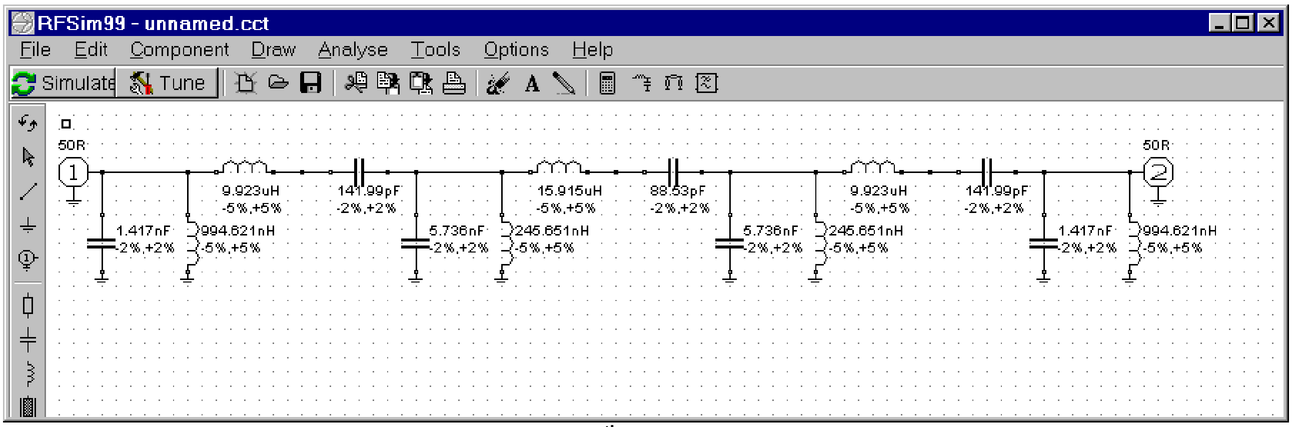


Figure 19: Band Pass 7th order Butterworth filter

E3.2 Simulation Results

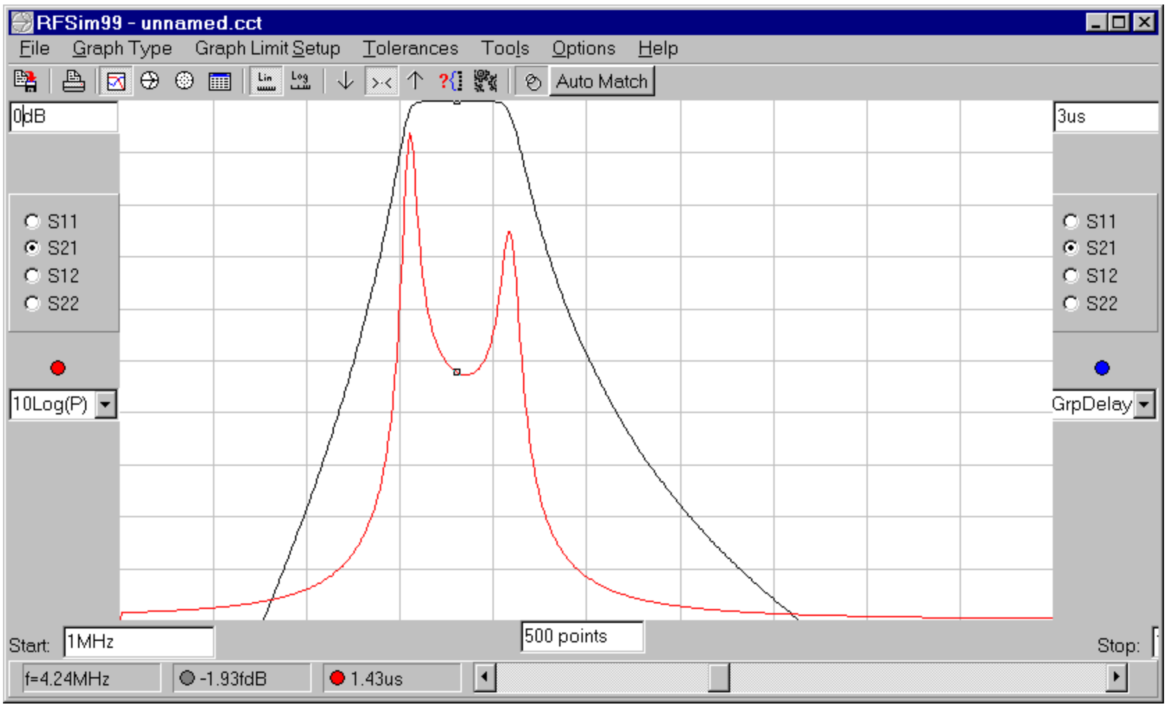


Figure 20: Attenuation (10 dB/div) and Group Delay (300 ns/div) in the range 1 MHz to 10 MHz

Due to the difficulty in getting a limited variation of the group delay within the narrow band of interest, it is suggested that the emission recordings, obtained with the use of this filter, are properly compensated (with the use of a complementary digital filter), for the group delay characteristic of the actual filter implementation.

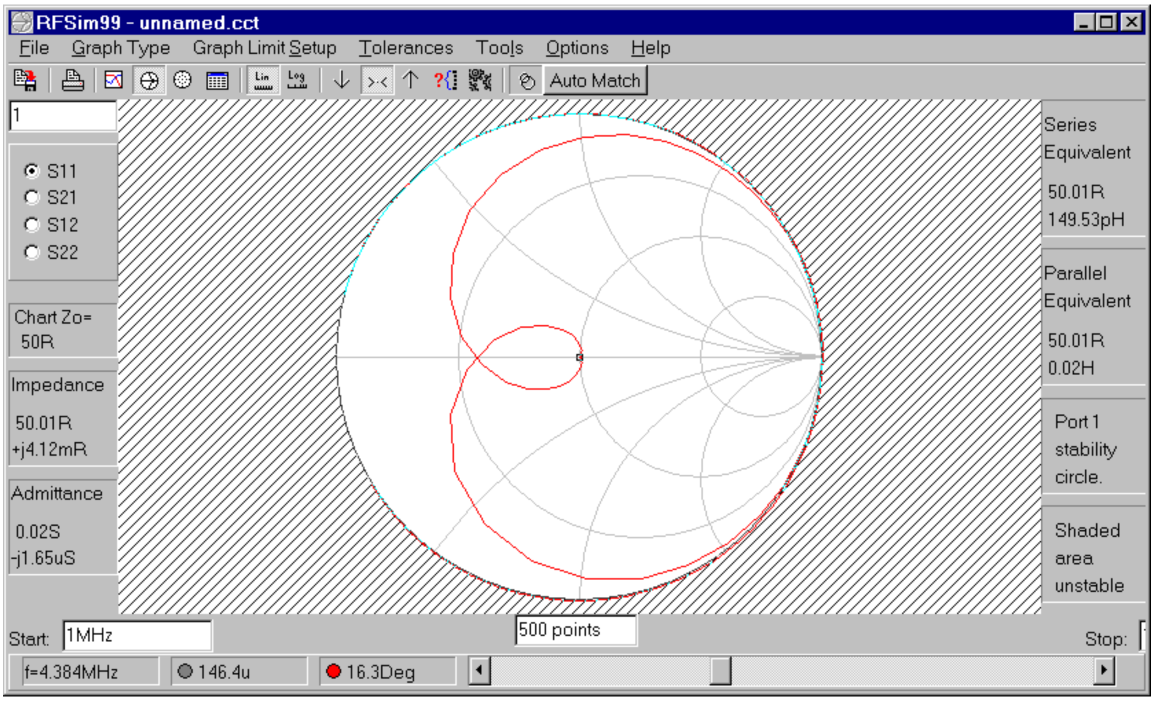


Figure 21: Input impedance in the range 1 MHz to 10 MHz

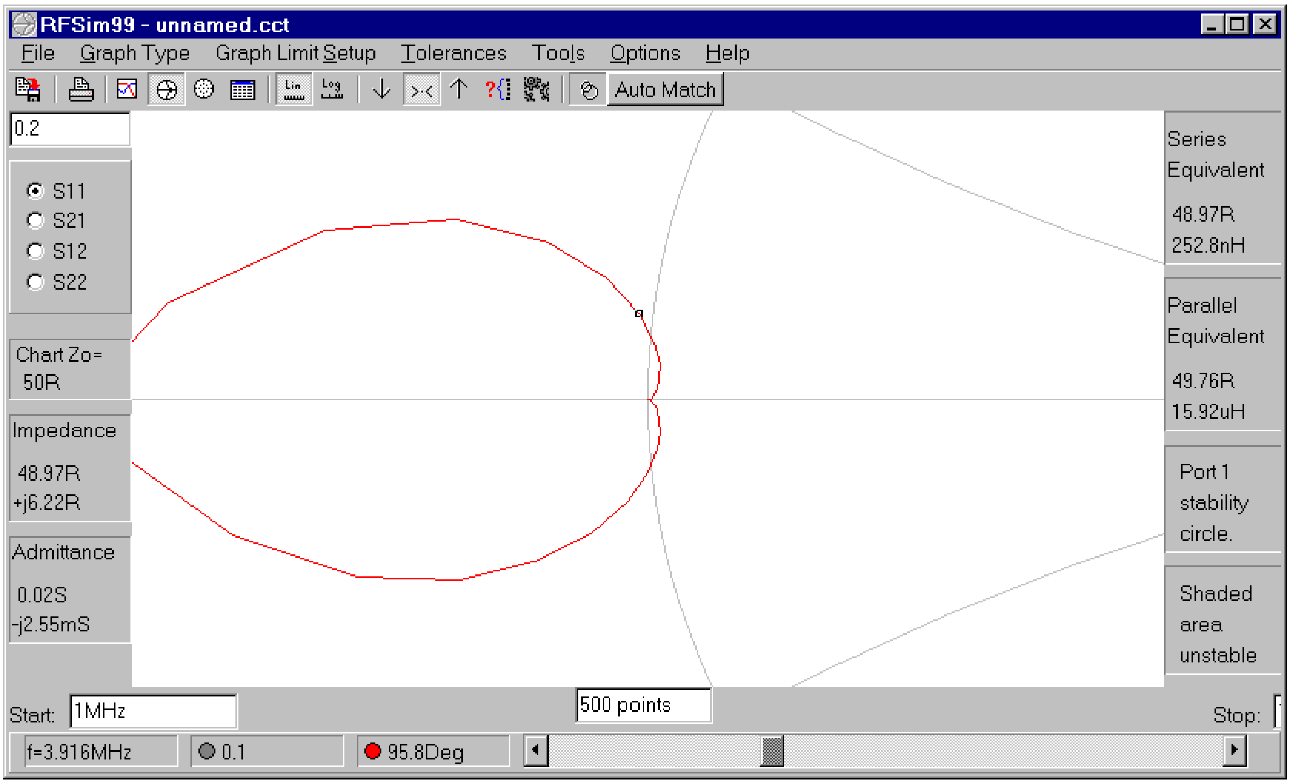


Figure 22: Input impedance (zoom) in the up-link range

E4 Wide Band Filter 1 MHz to 10 MHz

E4.1 General

The wide-band filter has the purpose to filter out all possible emission harmonics outside the range of interest for the Eurobalise Up-link bandwidth. This is needed in order to avoid possible saturation problems due to lower frequency, high level harmonics and aliasing errors due to high frequency contents.

The band of interest is between 1 MHz and 10 MHz.

E4.2 Design Solution

A Butterworth-type filter has been chosen for the basic needs of minimising the delay group variation within the bandwidth. The seventh order has been chosen as a trade off between circuit complexity and maximisation of out-band attenuation. The filter is composed of a high-pass section with a cut frequency of 1 MHz and a low pass section with a cut frequency of 10 MHz.

The following Figure 23 and Figure 25 give the schematic diagrams of the two filter sections and the value of each component.

Also for this filter post processing with complementary digital filters is recommended in order to compensate for the signal distortions caused by the Group Delay variations within the band of interest.

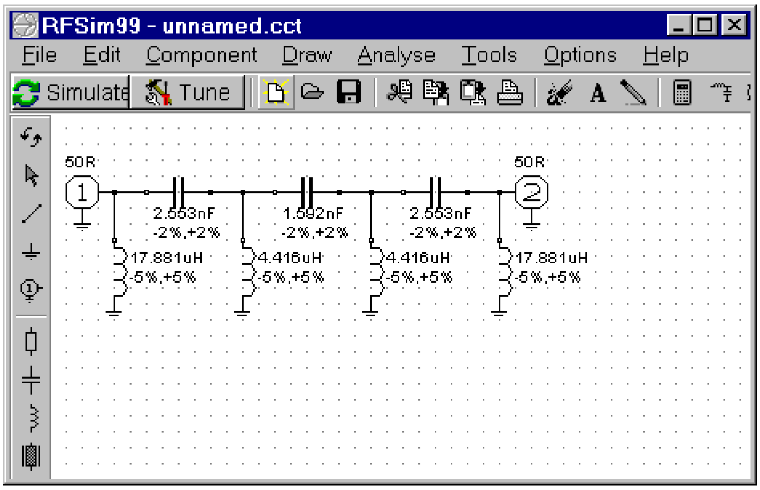


Figure 23: High pass section 7th order Butterworth filter

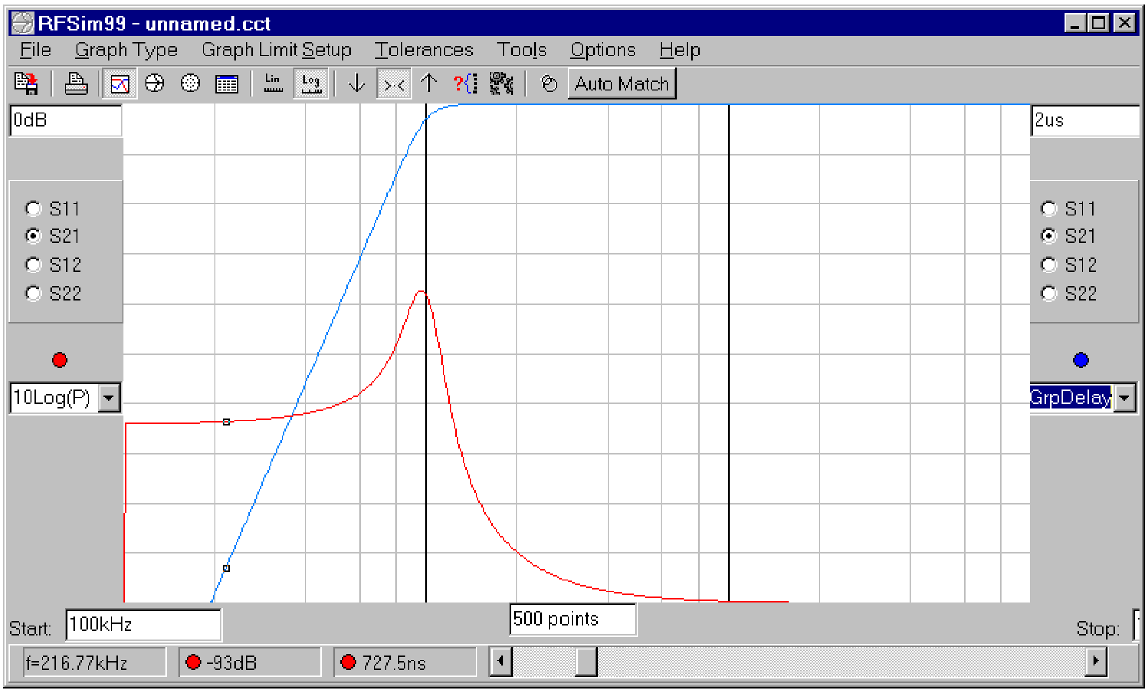


Figure 24: Attenuation and Group Delay of the High pass section

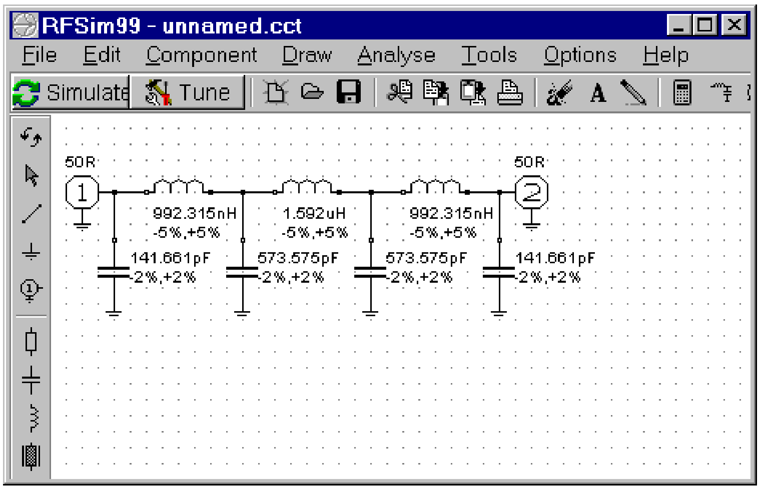


Figure 25: Low pass section 7th order Butterworth filter

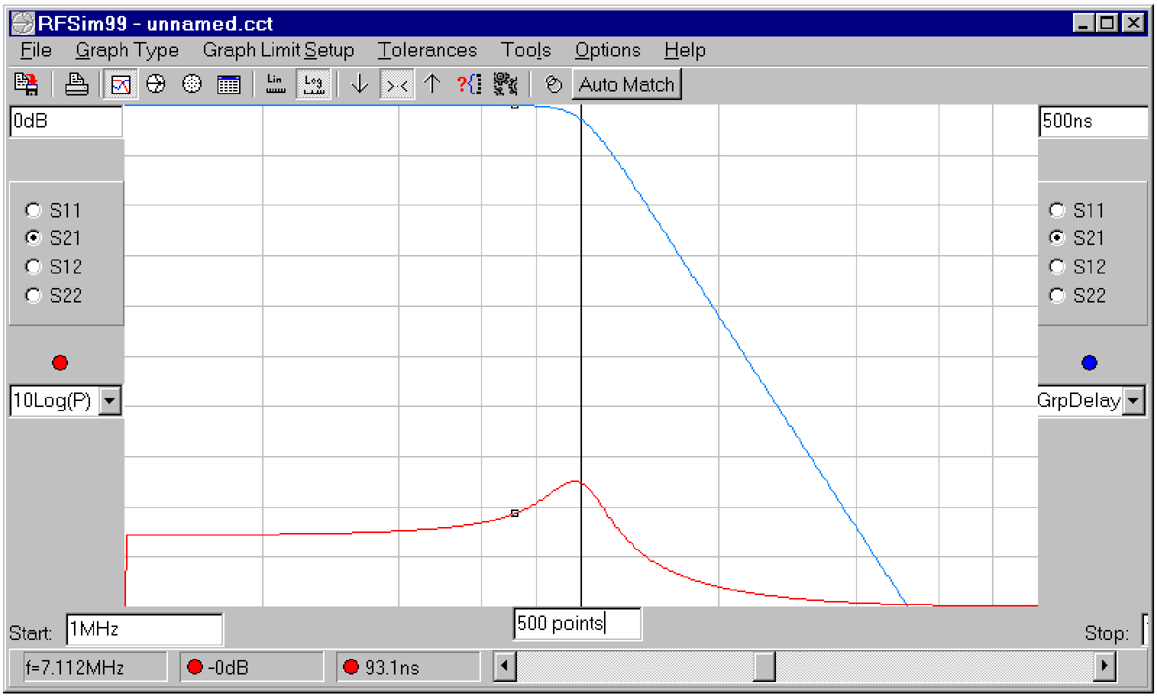


Figure 26: Attenuation and Group Delay of the Low pass section

Annex F (Informative), Intentionally Deleted

Annex G (Normative), Intentionally Deleted