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ALMA PROJECT

ALMA SYSTEM WIDE REQUIREMENTS

- ELECTROMAGNETIC COMPATIBILITY

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1. INTRODUCTION

1.1 Purpose

This part of the ALMA System Wide Requirements provides a formal guideline for Electromagnetic Compatibility (EMC) requirements to be applied in the ALMA project.
It has been prepared to assure with reasonable confidence that:

- Sub-systems and all other components that constitute the complete ALMA instrument can operate together without having their designated functionality affected by the intended EMC environment. This objective is achieved by having all these sub-systems and components confirm to a well specified maximum level for generation of Electromagnetic Interference (EMI) and assure that their functionality is not affected up to a corresponding level of external EMI.
- EMI levels at the antenna site at Chajnantor, Chile, are sufficiently low to permit high sensitivity radio astronomical observations not only in the current ALMA bands but also in other parts of the frequency spectrum that are allocated to the radio astronomy service.
- Susceptibility of sub-systems against EMI satisfies internationally accepted EMC criteria so that it precludes or limits hazards to personnel and equipment.

The primary intended reader audience consists of all people directly responsible for product management and development engineers contributing to the ALMA project.

1.2 Scope

The requirements in this guideline shall be applied to all electrical and electronic hardware products that constituent the ALMA instrument as are given in the ALMA product structure AD [3].
The EMC requirements are primarily intended to be enforced on equipment at the ALMA array site used during observation. However, as the other locations may also suffer from non-compliance less stringent EMC requirements shall be enforced for all electrical systems used on other locations.

Products that are components in a larger sub-system, which satisfies as a whole these EMC requirements, are exempted from these requirements.
Other exceptions to this rule can be made after consultation with and approval by the ALMA Systems Engineering Group (ASEG). General instructions about possible exceptions are discussed in chapter 3 of this document.
After initial approval by the AEC, the contents of this document are controlled by the ALMA Configuration Control Board.

1.3 Applicable documentation

The following documents of the exact issue shown form a part of this specification to the extent specified herein. Where no issue or date is indicated, the latest editions/revisions thereof and any amendments or supplements thereto in effect on the date of the Contract Documents shall be taken as valid. In the event of conflict between the documents referenced herein and the contents of this specification, the contents of this specification shall be considered a superseding requirement.

1.3.1 ALMA Specifications

AD [1] ALMA Management Plan (in preparation).
AD [2] ALMA Project Book (in preparation).
AD [3] ALMA Product Structure (in preparation).

In the event of a conflict between one of the above mentioned applicable documents and the contents of this document, the contents of this document shall be considered as a superseding requirement.

1.3.2 International standards related to EMC

1.3.2.1 Generic standards

AD [4] IEC 61000 series "Electromagnetic Compatibility".
AD [5] CISPR 11 "Industrial, scientific and medical (ISM) radio frequency equipment – Electromagnetic disturbance characteristics – Limits and methods of measurement".
AD [6] Recommendation ITU-R RA. 769-1 "Protection criteria used for radioastronomical measurements".
AD [7] MIL-STD-461E : Requirements for the control of EMI – Characteristics of subsystems and equipment.

1.3.2.2 Product / product family standards

AD [8] IEC 60478-3 "Stabilized power supplies, d.c. output – reference levels and measurement of conducted EMI".
AD [9] IEC 61204-3 "Low-voltage power supplies, d.c. output – part 3: "Electromagnetic Compatibility".
AD [10] IEC 61326-1 "Electrical equipment for measurement, control and laboratory use - EMC requirements".
AD [11] IEC 61543 "Residual current-operated protective devices (RCDs) for household and similar use - Electromagnetic compatibility".
AD [12] IEC 61547: "Equipment for general lighting purposes - EMC immunity requirements".
AD [13] IEC 61587-3 " Mechanical structures for electronic equipment – Electromagnetic shielding performance tests for cabinets, racks, subracks".
AD [14] IEC 61800-3 "Adjustable speed electrical power drive systems - EMC product standard including specific test methods".
AD [15] IEC 62040-2 "Uninterruptible power systems – EMC requirements".
AD [16] ETS 300 329 "Radio Equipment and Systems (RES); EMC for Digital Enhanced Cordless Telecommunications (DECT) equipment".
AD [17] ETS 300 447 "Radio Equipment and Systems (RES); EMC standard for VHF FM broadcasting transmitters".
AD [18] ETS 300 682 "Radio Equipment and Systems (RES); EMC standard for On-Site Paging equipment".
AD [19] EN 300 386-2 "Electromagnetic compatibility and Radio spectrum Matters (ERM); Telecommunication network equipment; EMC requirements; Part 2: Product family standard".

1.4 Reference documents

RD [1] ALMA Project Book Chapter 16 – Site Development.

1.5 Acronyms

ac / a.c.	Alternating current
ALMA	Atacama Large Millimeter Array
ASEG	ALMA Systems Engineering Group
CE	Conformité Europeenne
CEN	European Standards Coordinating Committee
CENELEC	European Committee for Electrotechnical Standardisation
CISPR	Comité International Spécial des Perturbations Radioélectriques
CSA	Canadian Standards Association
dc / d.c.	Direct current
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EMP	Electromagnetic Pulse
EN	European Norm
ESD	Electrostatic Discharge
EUT	Equipment Under Test
HF	High Frequency
IEC	International Electrotechnical Commission
IF	Intermediate Frequency
ISM	Industrial, Scientific and Medical
ISO	International Organisation for Standardisation
ITE	Information Technology Equipment
ITU	International Telecommunication Union
MIL	Military
OSF	Operational Support Facility
PBC	Protective Bonding Circuit
PCB	Printed Circuit Board
QP	Quasi Peak
RF	Radio Frequency
rms / r.m.s.	Root mean square
STD	Standard
Tbd / T.b.d.	To be determined
THD	Total Harmonic Distortion
UL	Underwriters Laboratories
VDE	Verband Deutscher Elektrotechniker

1.6 Definitions

Definitions related to EMC may be found in the EEC Directive 89/336/EEC, in chapter 161 of IEC 60050 ("International Electrotechnical Vocabulary") and in CISPR publications. Some of these definitions are given in this chapter.

Where the terms 'voltage' and 'current' are used, they imply the r.m.s. values, unless otherwise specified.

Burst
A sequence of a limited number of distinct pulses or an oscillation of limited duration.

(Electromagnetic) compatibility level
The specified maximum electromagnetic disturbance level expected to be impressed on a device, equipment or system operated in particular conditions.
Note. In practice the electromagnetic compatibility level is not an absolute maximum level, but may be exceeded with a small probability.

Disturbance level
The value of a given electromagnetic disturbance, measured in a specified way.

Electromagnetic compatibility (EMC)
The ability of an equipment or system to function satisfactorily in its electromagnetic environment without introducing intolerable electromagnetic disturbances to anything in that environment.

Electromagnetic disturbance
Any electromagnetic phenomenon which may degrade the performance of a device, equipment or system, or adversely affect living or inert matter.
Note. An electromagnetic disturbance may be an electromagnetic noise, an unwanted signal or a change in the propagation medium itself.

Electromagnetic environment
The totality of electromagnetic phenomena existing at a given location.

Electromagnetic interference (EMI)
Degradation of the performance of an equipment, transmission channel or system caused by an electromagnetic disturbance.
Note. Disturbance and interference are respectively cause and effect.

Emission level (of a disturbing source)
The level of a given electromagnetic disturbance emitted from a particular device, equipment or system in a specified way.

Emission limit
The specified maximum emission level of a source of electromagnetic disturbance.

Enclosure port
The physical boundary of the apparatus through which electromagnetic fields may radiate or impinge.

Harmonic (component)
A component of order greater than one of the Fourier series of a periodic quantity.

(Total) harmonic factor
The ratio of the r.m.s. value of harmonic content to the r.m.s. value of an alternating quantity.

Immunity (to a disturbance)
The ability of a device, equipment or system to perform without degradation in the presence of an electromagnetic disturbance.

Immunity level
The maximum level of a given electromagnetic disturbance incident on particular device, equipment or system for which it remains capable of operating at a required degree of performance.

Immunity limit
The specified minimum immunity level.

Mains signaling
Use of the distribution network for the transmission of signals.

Port
Particular interface of the specified apparatus with the external electromagnetic environment.

(Electromagnetic) susceptibility
The inability of a device, equipment or system to perform without degradation in the presence of an electromagnetic disturbance.

Interharmonics
Discrete or wide-band spectrum frequencies which are not integer multiples of the power frequency fundamental.

Short (supply) voltage interruption
The disappearance of the supply voltage for a period of time not exceeding 1 min.

Voltage dip
A sudden reduction of the voltage at a point in an electrical system, followed by voltage recovery after a short period of time, from half of a cycle to a few seconds.

Voltage fluctuation
A cyclical variation of the voltage envelope or a series of random voltage changes, the magnitude of which does not normally exceed the range of operational voltage changes mentioned in IEC Publication 60038 (up to ±10%).

Voltage surge
A transient voltage wave characterized by a rapid increase followed by a slower decrease.

Voltage unbalance (imbalance)
In a polyphase system, a condition in which the r.m.s. values of the phase voltages or the phase angles between consecutive phases are not all equal.

2. REQUIREMENTS

2.1 General

Requirements for EMC are to be evaluated on a case to case basis. A basic set of general requirements is formulated in the following sections. In exceptional cases, based on an evaluation of the EM environment and the peculiarities of the equipment, specific requirements may have to be added.
A contractor shall consult the authors on EMC related issues in case it is uncertain whether a device, equipment or system will be able to be compatible.
Applicable standards on EMC are the generic standards mentioned in section 1.3.2.1 and/or product specific ones mentioned in section 1.3.2.2. The requirements in this chapter denote the general requirements based on generic standards. Where products have their own product or product family standard (for some examples see section 1.3.2.2) they may be accepted even if the limits noted down in this section will not be fulfilled.
Note that the ITU RA.769-1 recommendation addresses radio astronomy specific frequencies with their maximum radiated interference values. The requirements for these frequencies shall be considered supplemental to all general and product/product family requirements.

2.2 Immunity requirements

2.2.1 Performance criteria

As a general rule for immunity tests, the test result is positive if the equipment shows its immunity, based on the applicable performance criterion, for all the period of application of the test. At the end of the tests the EUT fulfils the functional requirements established in the technical specification, taking into account that insignificant effects may also be acceptable.

Performance criteria are :

Performance criterion	Description
A	Normal performance within limits specified by the manufacturer, requestor or purchaser.
B	Temporary loss of function or degradation of performance which ceases after the disturbance ceases, and from which the EUT recovers its normal performance, without operator intervention.
C	Temporary loss of function or degradation of performance, the correction of which requires operator intervention.
D	Loss of function or degradation of performance which is not recoverable, owing to damage to hardware or software, or loss of data.

Table 2-1: Performance criteria for immunity tests

2.2.2 Conducted immunity

2.2.2.1 Harmonic voltages – individual harmonics and THD

The immunity limits for individual harmonic voltages shall be the products of the compatibility levels given in IEC 61000-2-2 (where values are given on the levels of disturbance that can be expected in low-voltage power supply systems) and a factor of 1.6 in order to add a margin.

Performance criterion: A

Where several harmonics occur simultaneously the combined effect may be expressed as a total distortion factor. The immunity limit for the total distortion factor shall be 8%.

Performance criterion: A

This requirement may be applied to equipment sensitive to precise zero-crossing in time on the a.c. mains or to specific harmonic components.

2.2.2.2 Rectangular (step) voltage fluctuations

The immunity limit for rectangular (step) voltage changes shall be

$\Delta U = \pm 12\%$ of U_n

with repetition period T = 5÷10 s and duration t = 2÷3 s.

Performance criterion: A

2.2.2.3 Voltage dips

The immunity limits for voltage dips shall be

$\Delta U_1 = -30\%$ of U_n for 10 ms – performance criterion B

$\Delta U_2 = -50\%$ of U_n for 100 ms – performance criterion C

2.2.2.4 Voltage interruptions

The immunity to short AC voltage interruptions ($\Delta U \leq -95\%$) shall be up to 5000 ms with performance criterion C.

2.2.2.5 Voltage (current) surges

The following classes of installation are given in annex B of IEC 61000-4-5.

Class	Description
0	Well-protected electrical environment, often within a special room.
1	Partly protected electrical environment.
2	Electrical environment where cables are well separated, even at short runs.
3	Electrical environment where cables run in parallel.
4	Electrical environment where the interconnections are running as outdoor cables along with power cables, and cables are used for both electronic and electric circuits.
5	Electrical environment for electronic equipment connected to telecommunication cables and overhead power lines in a non-densely populated area

Table 2-2: Installation classes for electrical environments

Test levels shall be selected according to these installation conditions. Next table gives recommended test levels according to IEC 61000-4-5.

Installation class	Test levels							
	Power supply coupling mode		Unbalanced operated circuits/lines, LDB coupling mode		Balanced operated circuits/lines coupling mode		SDB, DB[1] coupling mode	
	Line to line kV	Line to earth kV	Line to line kV	Line to earth kV	Line to line kV	Line to earth kV	Line to line kV	Line to earth kV
0	NA	NA	NA	NA	NA	NA	NA	NA
1	NA	0.5	0.5	0.5	NA	0.5	NA	NA
2	0.5	1.0	1.0	1.0	NA	1.0	NA	0.5
3	1.0	2.0	2.0	2.0[3]	NA	2.0[3]	NA	NA
4	2.0	4.0[3]	2.0	4.0[3]	NA	2.0[3]	NA	NA
5	[2]	[2]	2.0	4.0[3]	NA	4.0[3]	NA	NA

Acronyms : DB = data bus/line, SDB = short-distance bus, LDB = long distance bus, NA = not applicable

[1] Limited distance, special configuration, special layout, 10-30 m max. : no test up to 10 m, class 2
[2] Depends on the class of the local power supply system
[3] Normally tested with primary protection

Table 2-3: Test levels for surge immunity test

The surge waveform for classes 1 to 4 : rise time T_r is1,2 µs and hold time T_h is 50 µs (8/20 µs for current injection). For class 5 a 10/700µs waveform is needed for long-distance signal circuits/lines

For the ALMA site environment class 4 with performance criterion B shall mostly be required. The OSF and other sites will normally use class 3 severity levels.

2.2.2.6 Electrical Fast Transient (EFT) / Burst

The recommended selection of test levels noted down in the following table shall be done according to the characteristics of the electromagnetic environment (e.g. well-protected environments like computer control rooms versus industrial environments where higher levels are applicable). For testing I/O, control, signal and data EUT's ports use half the test voltage values applied on power supply ports.

For ALMA site one should normally take level 3 for a.c. power ports and PE terminals, performance criterion B. At OSF level 2 may mostly be sufficient

Environment	Voltage level (kV)
1 (well–protected environment[1])	0.5
2 (protected environment)	1.0
3 (typical industrial environment)	2.0
4 (severe industrial environment)	4.0

[1] See IEC 61000-4-4 for a detailed description on levels 1-4.

Table 2-4: EFT environments

Transient shape : Rise time T_r = 5 ns, Hold time T_h = 50 ns. Repetition rate : 5 kHz

2.2.2.7 Electrostatic Discharge (ESD) requirements

The object of this requirement is to establish a common and reproducible basis for evaluating the performance of equipment when subjected to ESD.
Contact discharge is preferred over air discharge as a test method. Typical test points to be considered are points on metallic sections of a cabinet, operator accessible points in the control or keyboard area and accessories like indicators, LED's, slots, connector hoods, etc.

Required compliance levels according to IEC 61000-4-2 are:

Level	Contact discharge test voltage (kV)	Air discharge test voltage (kV)
1. Relative humidity as low as 35%, anti-static material	2	2
2. Relative humidity as low as 10%, anti-static material	4	4
3. Relative humidity as low as 50%, synthetic material	6	8
4. Relative humidity as low as 10%, synthetic material	8	15

For ALMA site the following values shall be chosen:

	Level	Criteria
Air-Discharge	4: 2 to 15 kV in 2kV increments	Criteria A up to 8kV Criteria B above 8kV
Contact	4: 2 to 8kV in 2kV increments	Criteria A up to 4kV Criteria B above 4kV

Table 2-5: ESD requirements on ALMA Site

The OSF environment poses a similar stringent environment since operators may not have discharge facilities and expensive equipment is involved.
For other environments level 3 may be chosen :

	Level	Criteria
Air-Discharge	2 to 8 kV in 2kV increments	Criteria A up to 4kV Criteria B above 4kV
Contact	2 to 4kV in 2kV increments	Criteria A up to 2kV Criteria B above 2kV

Table 2-6: Level 3 ESD requirements

2.2.2.8 Immunity to conducted disturbances induced by RF fields

The source of disturbance covered by this requirement is basically an EM field, coming from intended RF transmitters, that may act on the whole length of cables connected to an installed equipment. Cables then may act as passive receiving antenna networks of several wavelengths. The frequency range shall be from 150 kHz – 80 MHz and levels shall be similar to section 2.2.3.1 according to the appropriate class.
This requirements may not be applicable to systems on Chajnantor since there likely will not be intentional transmitters in that frequency range. On other locations like OSF these transmitters may be much more likely and therefore this requirements shall be verified.
The test method can be found in IEC 61000-4-6.

2.2.3 Radiated immunity

2.2.3.1 RF field immunity

Different types of environments may be encountered. The following environment classes are defined by IEC 61000-4-3:

Class	Description
1	Low-level EM radiation environment. Levels typical of local radio/television stations located at more than 1 km, and transmitters/receivers of low power.
2	Moderate EM radiation environment. Low power portable transceivers (typically less than 1 W rating) are in use, but with restrictions on use in close proximity to the equipment. A typical commercial environment.
3	Severe EM radiation environment. Portable transceivers (2 W rating or more) are in use relatively close to the equipment but not less than 1 m. High power broadcast transmitters are in close proximity to the equipment and ISM equipment may be located close by. A typical industrial environment.
x	Special cases of EM radiation environment.

Table 2-7: Classes of EM radiation environments

The related field strength the system shall be immune to -according to class- is denoted in the next table.

Class	Field strength (V/m)
1	1
2	3
3	10
x	-

Table 2-8: RF field immunity levels

The frequency range of the field shall be chosen from 80-1000 MHz and the signal shall be a 1 kHz sinewave which is 80 % amplitude modulated. Dependant on the location, an extra requirement may be placed for protection against RF emissions from digital radio telephones typically operating in the frequency range from 800-960 MHz and from 1.5 – 2.0 GHz keeping the same values as in Table 2-8. Obviously the major system to be considered will be the receiver cabin with receivers where RF emission as well as susceptibility to RF fields up to very high frequencies plays a key role. Apart from being immune to the above mentioned signals such a system shall also ideally be immune to RF fields in all observational frequency bands up to a THz. Requirements on RF field emission, noted down in section 2.3.1.3 must prevent that RF fields created by equipment installed on the system interferes with observations.

Both ALMA Site and OSF shall primarily be considered to represent a class 2 environment.

2.2.3.2 Power frequency magnetic field immunity

Where a risk exists that equipment may be influenced by magnetic fields originating from power frequency currents one shall consider the requirements noted down in IEC 61000-4-8.
Requirements for a continuous power frequency magnetic field may be chosen from the next table, taking into account a suitable level.

Level	Magnetic field strength (A/m)
1. Environmental level where sensitive devices using electronic beam (like monitors) can be used.	1
2. Well protected environment – Typically household and office areas far away from earth protection conductors, areas of industrial installations and high-voltage substations.	3
3. Protected environment – Typically commercial, control building and computer room areas of industrial installations.	10
4. Industrial environment – Typically areas of heavy industrial installations and high-voltage substations.	30
5. Severe industrial environment – Switchyard areas of heavy industrial installations and medium/high-voltage substations.	100

2.3 Emission Requirements

The radiated and conducted electromagnetic disturbances emitted shall not exceed the limits set in the sections below. Margins for emission shall be provided based on system operational performance requirements, tolerances in system hardware, and uncertainties involved in verification of system-level design requirements. Critical systems initially shall have a margin of at least 6 dB. In future certain emission limits may need to be changed due to information gathered on the immunity of critical systems.

2.3.1 Conducted emission

2.3.1.1 Harmonic currents

The harmonic currents injected into the power distribution system shall not exceed the percent ratios indicated by the following table where I_1 = rated fundamental current and I_n = harmonic current component.

Harmonic number n	Admissible harmonic current I_n/I_1 (%)	Harmonic number n	Admissible harmonic current I_n/I_1 (%)
3	21.6	21	≤ 0.6
5	10.7	23	0.9
7	7.2	25	0.8
9	3.8	27	≤ 0.6
11	3.1	29	0.7
13	2	31	0.7
15	0.7	≥ 33	≤ 0.6
17	1.2		
19	1.1	Even	$\leq 8/n$ or ≤ 0.6

Table 2-9: Harmonic current emission limits

2.3.1.2 Conducted RF disturbance voltage

Conducted radio-frequency terminal disturbance voltages on mains lines shall not be emitted in excess of the values given by the following table. Measurement shall be done according to CISPR 11.

Mains terminal disturbance voltage limits dB(µV)		
Frequency band (MHz)	**Quasi-peak**	**Average**
0.009 – 0.15	TBD	TBD
0.15 – 0.50	66 Decreasing linearly with logarithm of frequency to 56	56 Decreasing linearly with logarithm of frequency to 46
0.50 – 5	56	46
5 – 30	60	50

Table 2-10: Mains terminal RF disturbance voltage limits

2.3.1.3 Voltage fluctuations and flicker

Voltage fluctuations and flicker injected into a power distribution system shall not exceed the limits standardized by IEC 61000-3-5.

2.3.2 Radiated emission

2.3.2.1 Radiated field emission limits

Radiated field emission limits dB(µV/m)			
Frequency band (MHz)	Emission limit	According to :	Maximum emission level at certain frequencies [1)]
30 – 230	30 QP (at 30 m)	CISPR 11	According to ITU-R RA. 769-1 (AD [6]), see section 2.3.2.2
230 – 1000	37 QP (at 30 m)	CISPR 11	
1000 – 18000	see chart below, upper line	MIL-STD-461E test RE102	
18000-40000	see chart below, upper line	MIL-STD-461E test RE102/RE103	
40000-…….			
[1)] This standard adds additional requirements on fixed frequencies important to radioastronomy.			

Table 2-11: Radiated field emission limits

The requirements for frequencies above 1000 MHz are initially meant for equipment and systems that could have electromagnetic influence on the observational data. In the receiver area the full frequency range shall be analysed whereas systems that may have impact on the down-converted data stream shall be evaluated for radiated emission up to the highest IF.

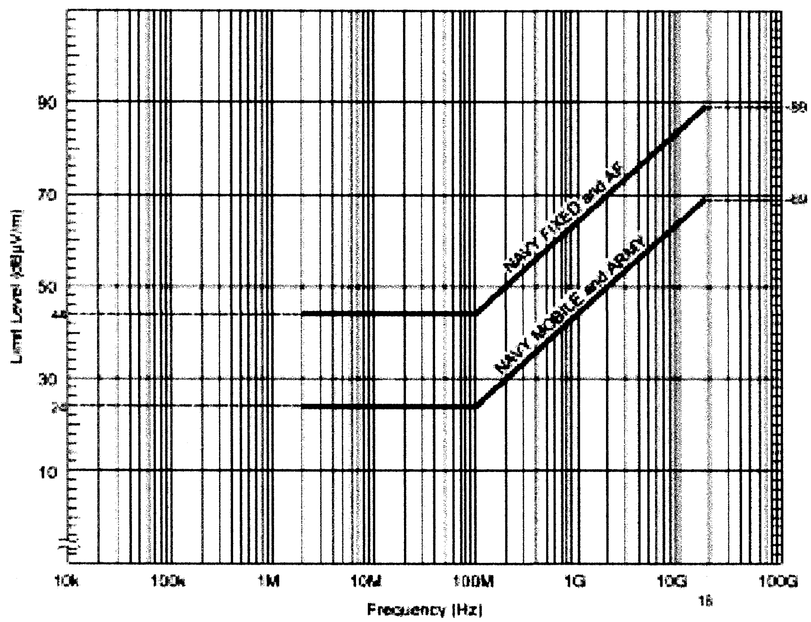

Figure 2-1: Emission levels above 1 GHz defined by MIL-STD-461E

2.3.2.2 ITU recommendations

				SYSTEM SENSITIVITY[1]		HARMFUL INTERFERENCE LEVELS[1] [2]		
Centre frequency[3] f_c (MHz)	Assumed bandwidth Δf_A (MHz)	Minimum antenna noise temperature T_A (K)	Receiver noise temperature T_R (K)	Temperature ΔT (mK)	Power Spectral density ΔP (dB(W/Hz))	Input power ΔP_H (dBW)	Power flux-density $S_H \Delta f_A$ (dB(W/m^2))	Spectral power flux-density $S_H \Delta f_A$ (dB(W/(m^2.Hz)))
13.385	0.05	60000	100	4250	-222	-185	-201	-248
25.610	0.120	20000	100	917	-229	-188	-199	-249
73.8	1.6	1000	100	14	-247	-195	-196	-258
151.525	2.95	200	100	2.76	-254	-199	-194	-259
325.3	6.6	40	100	0.86	-259	-201	-189	-258
408.5	3.9	25	100	1.00	-259	-203	-189	-255
611	6.0	15	100	0.74	-260	-202	-185	-253
1413.5	27	10	20	0.091	-269	-205	-180	-255
1665	10	10	20	0.15	-267	-207	-181	-251
2695	10	10	20	0.15	-267	-207	-177	-247
4995	10	10	20	0.15	-267	-207	-171	-241
10650	100	12	20	0.05	-272	-202	-160	-240
15375	50	15	30	0.10	-269	-202	-156	-233
23800	400	15	50	0.051	-271	-195	-147	-233
31550	500	18	100	0.083	-269	-192	-141	-228
43000	1000	25	100	0.063	-271	-191	-137	-227
89000	6000	30	150	0.037	-273	-185	-125	-222
110500	11000	40	150	0.029	-274	-184	-121	-222
166000	4000	40	150	0.048	-272	-186	-120	-216
224000	14000	40	200	0.032	-274	-182	-114	-215
270000	10000	40	200	0.038	-273	-183	-113	-213

Table 2-12: Threshold levels of interference detrimental to radioastronomy continuum observations (acc. to recommendation ITU-R RA.769-1)

[1] An integration time of 2000 s has been assumed; if integration times of 15 min, 1h, 2h, 5h or 10h are used, the relevant values in the tables should be adjusted by +1.7, -1.3, -2.8, -4.8 or –6.3 dB respectively.

[2] The interference levels given apply for measurements of the total power received by a single antenna. Less stringent levels may be appropriate for other types of measurements.

[3] Calculation of interference levels is based on the centre frequency shown in this column although not all regions have the same allocations.

2.3.2.3 Conversion of ITU limits

The following table denotes the ITU harmful interference levels of section 2.3.2.2 in dB (μV/m).

The conversion formula that has been applied is :

$$E(\mathrm{dB}\,\mu\,\mathrm{V/m}) = \frac{P(\mathrm{dBW/m}^2) + 10\log(120\pi)}{2} + 120$$

Centre frequency f_c (MHz)	Interference level dB (μV/m)	Centre frequency f_c (MHz)	Interference level dB (μV/m)	Centre frequency f_c (MHz)	Interference level dB (μV/m)
13.385	32.4	1413.5	42.9	31550	62.4
25.610	33.4	1665	42.4	43000	64.4
73.8	34.9	2695	44.4	89000	70.4
151.525	35.9	4995	47.4	110500	72.4
325.3	38.4	10650	52.9	166000	72.9
408.5	38.4	15375	54.9	224000	75.9
611	40.4	23800	59.4	270000	76.4

Table 2-13: ITU-R RA.769-1 harmful interference levels in dB(μV/m)

2.4 Applicability

The ALMA project includes development of four functionally and geographically separated sites (taken from ALMA Project Book, chapter 16 "Site Development", RD [1]).
These are:

1. The array site in the Altiplano of the second Region of Chile near Cerro Chajnantor;
2. The Operational Support Facility (OSF);
3. A communications link, or *highway*, connecting the OSF to the Chajnantor array site;
4. The Administrative office in Santiago.

Applicability of EMC requirements for these locations are generally noted down in the respective sections containing the requirements.

2.4.1 Exceptions to EMC requirements

2.4.1.1 Components

Products that are components in a larger sub-system, which satisfies these EMC requirements, are exempted from these requirements. For granting exemption it is necessary that the specifications of the product clearly state in which sub-system it will be used and how it should be installed and operated so that the sub-system fulfils the applicable EMC requirements. Components that are not part of a tested system shall be verified according to their product or product family standard, if existing.

2.4.1.2 Special sub-systems

For some products it will not be viable to meet the EMC requirements that are specified in this document for a/o technical and economical reasons (e.g. sensitive components in the receiver system).

For these special cases, after justification and approval, a relaxed set of EMC requirements can be applied. The diminished EMC specifications of the product must be compensated by other measures to assure the intended operation.
E.g. for the sensitive receiver system the ESD requirement may be relaxed provided that additional handling measures that limit the ESD threat are given.

2.4.1.3 Waiver procedure

The standard ALMA waiver procedure shall be used.

2.5 Proof of conformity

Proof of conformity shall be either by measurement, simulation or analysis or a combination of these. It is intended to have available a set of measurement instruments for this purpose.

3. EMC GUIDELINES

3.1 Scope

The following sections list guidelines regarding electromagnetic compatibility. Attention is drawn to the fact that EMC protection and safety requirements can have common aspects, such as earthing and protection against overvoltages and lightning. It is important to bear in mind that the safety aspects take precedence over EMC protection procedures. In some cases, there might be an alleged conflict between safety-related procedures and EMC-related ones. Safety shall always prevail, so that in such cases alternate EMC-related measures shall be sought.

3.2 Partitioning

- Partition the system into critical and non-critical sections.
- Determine which circuits will be noisy or susceptible and which will be not.
- Lay them out in separate areas as far as possible.
- Separate digital and analogue systems.
- Select internal and external interface points to allow optimum common-mode current control.

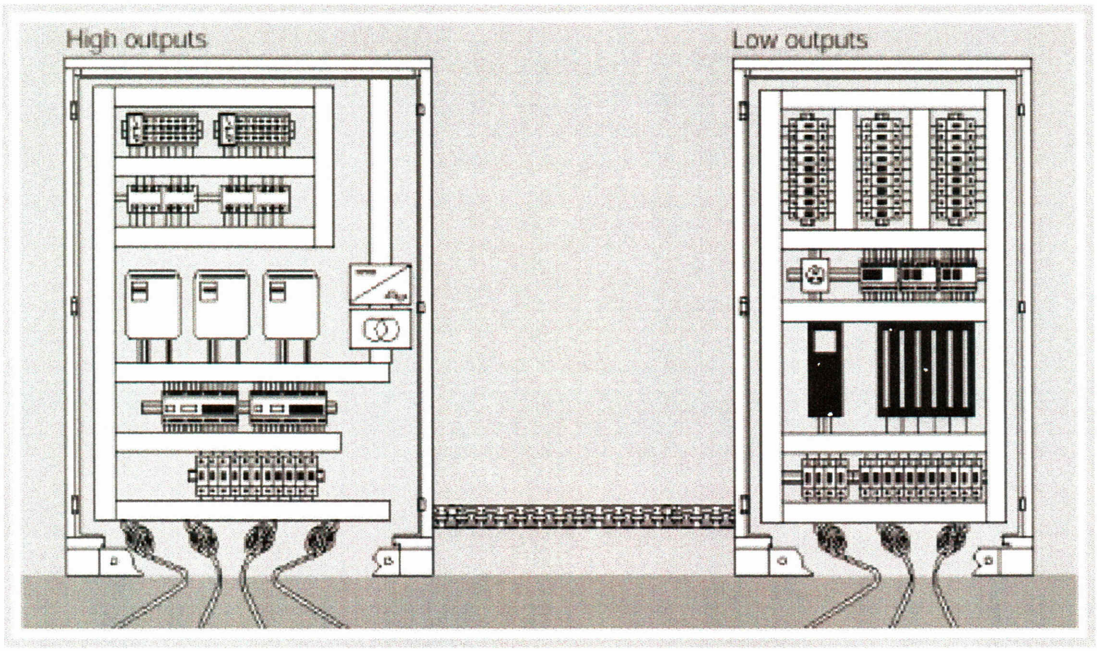

Figure 3-1: Functional enclosure layout - spatial division

3.3 Selection of components

- Select components and circuits with EMC in mind.
- Use slow (as slow as possible) and/or high immunity logic.
- Minimise rise/fall times on signal and clock edges.
- Use good RF decoupling, close to the origin.
- Use low impedance capacitors (e.g. ceramic multi-layer).
- Minimise signal bandwidth, maximise levels.
- Use low pass filters.
- Minimise output drive from clock circuits.

- Provide power supplies of adequate (noise-free) quality.
- Consider a watchdog circuit on every microprocessor.
- Use surface mounted devices (SMD) or Chip Scale Package (CSP) where possible.

3.4 PCB layout

- Track all signal lines on the board, avoid 'flying leads' across the board.
- Ensure proper signal returns; if necessary include isolation to define preferred current paths.
- Keep interference paths segregated from sensitive circuits.
- Minimise ground inductance with thick gridding or ground plane(s), use power plane where possible.
- Minimise enclosed loop areas in high current, high di/dt or sensitive circuits.
- Minimise surface areas of nodes with high dv/dt.
- Minimise HF and RF track length and component leadout length.
- Use wide tracks for power lines and decouple at local boundaries (use 'low Q' RLC filters).
- Avoid overlapping power planes.
- If possible make tracking run orthogonal between adjacent layers.
- Use track mitring (bevelling the edges at corners) and avoid track stubs.
- Do not leave any floating conductor areas, if possible connect to ground plane.
- On sensitive components and terminations use surrounding guard ring and ground fill, where possible.
- If used, only connect the guard ring to ground at a single point and make no other use of it.
- Avoid slit apertures in the PCB layout, particularly in ground planes or near current paths.

3.5 Cables

- Avoid parallel runs of signal and power cables.
- Use signal cables and connectors with adequate screening.
- Use twisted pair if appropriate.
- Run cables away from apertures in the shielding, close to conductive grounded structures.
- Avoid resonant lengths (close to the quarter wavelength of the signal frequency) where possible.
- Consider damping cables with ferrite suppressors.
- Ensure that cable screens are properly terminated to the correct type of connector.
- Where possible, try to keep all I/O cables in one area.
- Ensure filtering of cables and overvoltage protection at the terminations, especially for cables external to the system (if possible isolate the signals using e.g. fibre optic cable).

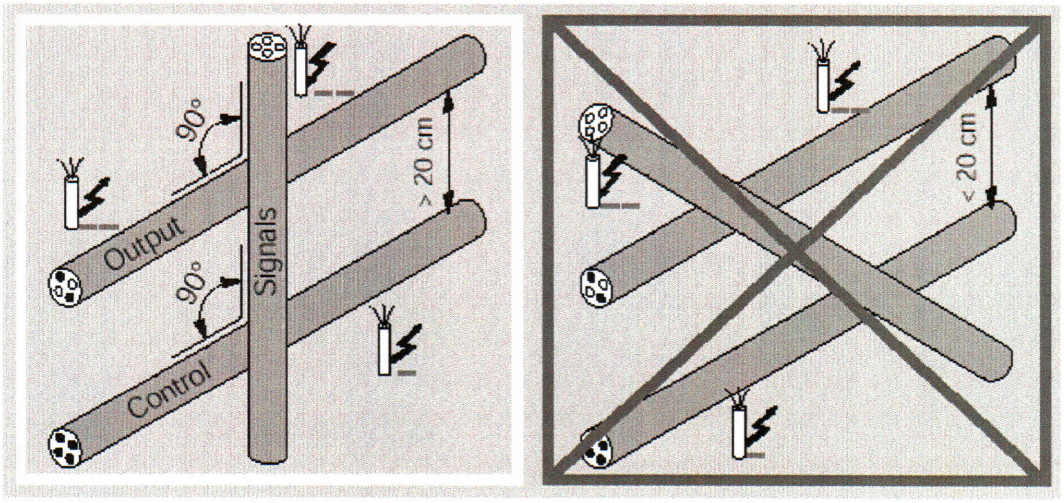

Figure 3-2: Right angled cable cross-overs to reduce EMI