CLUSTER

SOLAR TERRESTRIAL SCIENCE PROGRAMME

WAVE EXPERIMENT CONSORTIUM

EXPERIMENT INTERFACE DOCUMENT

PART B

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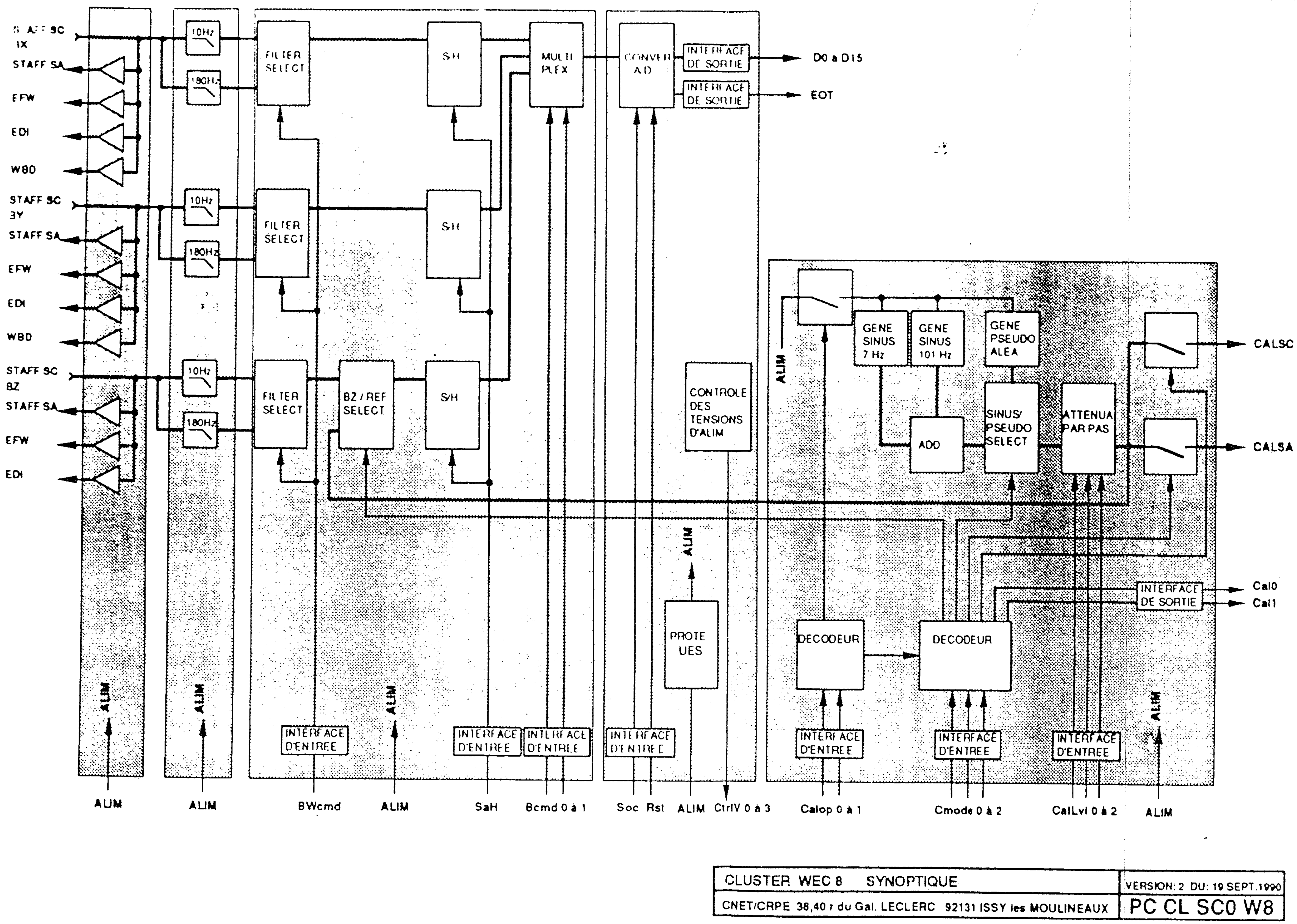
Fig: 1.2/2.2.b block diagram of STAFF / Magnetic Waveforms



EXPERIMENT INTERFACE DOCUMENT

PART B

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Issue	Rev.	Sec.	Page	Date	Changes	ECR No
Draft 1	0	All	All	01.10.88	First draft issue	
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2	0	C4	2	12.07.89	Distribution list slightly increased	
2	0	1	3-24	12.07.89	directories modified	
2	0	1	27	08.09.89	fig 1.1 completed	
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2	0	1	33-43	12.07.89	STAFF description modified	
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			8,9		EFW responsability & organigram upd	
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			56		PWR new specification of regulated voltages. Impact on the WEC harness (ECR 10)	

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			5		Editorial updates	
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			9-11		WEC Power consumption updates	
			12		Pyro, bridge resistance correction	
			13,14		OBDH i/f update according to EID A	
			15,16		i/f with the s/c, new description	
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1	3	0	15,16	08/12/90	description of i/f with the s/c addition of Annex 3	ECR 43
1	3	0	17-23	08/12/90	revision of WEC harness description	ECR 60

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Issue 1	0	9	7-17	08/12/90	Section 9/2 (MGSE) largely revised description of EFW plasma simulator description of WHISPER MGSE	ECR 39

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Issue 1	0	10	2	08/10/90	small clarification of deployment phase	ECR 40
Issue 1	0	11	2-12	10/10/90	New issue of the WEC PA Plan provided to STSP previous one not included in the EID Draft 2	
Issue 1	0	A.1		10/10/90	STAFF option no longer envisaged	
Issue 1	0	A.2	1-17	08/12/90	Version 1.3 (May, 30, 90) of WEC External Interfaces Definition	ECR 42
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Draft 1	0	All	All	01.10.88	First draft issue	
Draft 2	0	All	All	12.07.89	EID Draft 2 Large number of small corrections without any consequence on the experiment's design	WEC001
2	0	C4	2	12.07.89	Distribution list slightly increased	
2	0	1	3-24	12.07.89	directories modified	
2	0	1	27	08.09.89	fig 1.1 completed	
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			16		WISPER Directory update	
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			23		DWP Directory update	
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			13,14		OBDH i/f update according to EID A	
			15,16		i/f with the s/c, new description	
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Issue 1	0	8	 6,7 9	10/10/90	Editorial updates separated test matrix for WEC.6 and WEC.7 & 8 WBD test matrix update	ECR 38
Issue 1	0	9	7-17	08/12/90	Section 9/2 (MGSE) largely revised description of EFW plasma simulator description of WHISPER MGSE	ECR 39

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Issue 1	0	A.1		10/10/90	STAFF option no longer envisaged	
Issue 1	0	A.2	1-17	08/12/90	Version 1.3 (May, 30, 90) of WEC External Interfaces Definition	ECR 42
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1	1	4	all	06.09.91	complete update of the section TMM, TICD, HEB TICD details on page 13,15,17,19, 21,23,25,27	
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1	1	3	61 62/65 66 67,86 68,83 72,76,78 80 82 67,86 fig 3.5/1 A0	06.09.91	ss replaced by tsq awg 24 replaced by awg 26 efw/rtu,peu,pdu i/f completed csy awg 26 introduction of tsq 26 tp 24 replaced by tp 22 whisper hv i/f completed DWP/PWR command line s24 replaced by tp 24 PDU i/f completed updated accordingly	1075
		2 3	32 60,55 fig 3.5/1 A0	06.09.91	WEC 10 MICD completed WEC 10 connectors type corrected updated accordingly	0055
	1 2	2 4	29,30 23,24	24.04.92	WEC 9 MICD modified, details p 29 TICD updated accordingly	1076
	2 2	2 4	23,24 17,18	24.04.92	WEC 6 MICD completed, details p 23 TICD updated accordingly	1072
	1	3	41/45 47,50	06.01.92	IEL update S/C potential, Whisper distribution Dwp/Peace i/f & Fgm i/f	1077
	2	3	70	06.09.92	WEC7c pin assignment modified : Bxe, Bze, X feed back, Z feed back signal and return lines swapped	1091
	1	3	17,22	12.10.92	synchro i/f update	1079
	1	3	34 35	12.10.92	HK bit rate increase parameters list updated	1069 1080
	1	3	28,29 31,33	12.10.92	DWP OBDH i/f circuits modified	1081
	1 1 2	3	6,18 9to11 14,16	12.10.92	power distribution & i/f circuits power allocation & modes consump- tion updated	1090
	1	5	5,6	12.10.92	frequency plan completed	1083
	1	8	7,12 20	12.10.92	WEC5 & 10 qualification philosophy corrected & updated	1084

DOCUMENTATION CHANGE RECORD
(continue)

Issue	Rev.	Sec.	Page	Date	Changes	ECR No
1	2 1	2	72,73 19,20 76	31.01.93	WEC 1/4 mass reallocation MICD, inserts loads updated accordingly	1089

DOCUMENT CONFIGURATION

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1. GENERAL

SECTION 1 CONTENTS

1.1 KEY PERSONNEL AND RESPONSABLITY

Foreword

The Wave Experiment Consortium (WEC) is composed of five experiments which were combined to optimise the use of available spacecraft resources. These experiments are :

EFW (Electric Field and Wave experiment)

Principal Investigator : **G. Gustafsson**

STAFF (Spatio Temporal Analysis of Fields Fluctuations)

Principal Investigator : **N. Cornilleau-Wehrlin**

WHISPER (Waves of High Frequency and Sounder for Probing of Electron Density by Relaxation)

Principal Investigator : **P.M.E. Décréau**

WBD (Wide Band Data)

Principal Investigator : **D.A. Gurnett**

DWP (Digital Wave Processing)

Principal Investigator : **L.J.C. Woolliscroft**

PWR (Power Supply)

The Power Supply unit is not a scientific experiment but it has to distribute the Power to the WEC experiments.

The unit is under the responsibility of the **WECTCO**

The WEC has established, in agreement with the Cluster Project Office, a Technical Coordination Office **WECTCO** (Wave Experiment Consortium Technical Coordination Office), responsible for all technical aspects of interfaces between experiments of the WEC. This Coordination Office is led by :

WEC Technical Coordinator : **B. de la Porte des Vaux**

For scientific matters, the WEC has established a Scientific Board with an elected chairman :

WEC Scientific Board Chairman : **A. Roux**

1.1.1 W E C T C O, Wave Experiment Consortium Technical Coordination Office Key personnel and Responsibilities

a)b) WECTCO Directory and Responsibilities

Technical Coordinator: B. de la Porte (CRPE/CNET)

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SPAN :	CRPEIS::DELAPORTE
BITNET :	DELAPORT@FRCRPE51

The technical coordinator is assisted by the following persons:

- **A. Meyer**, Responsible for interfaces, harness, WEC integration, EMC cleanliness, thermal design, advice on radiation shielding.

CNET / RPE	same address as above
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SPAN :	CRPEIS::MEYER

- **A. Bouabdellah**, Responsible for WEC integrations

CNET / RPE	same address as above
Telephone :	[33 1] 45 29 51 82

- **J.A. Thompson**, Responsible for On-board Data Processing (Sheffield University), Interfaces with S/C and within WEC.

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Telefax :	[44] 742 739 826

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Telex :	910 525 1398
Telefax :	[1] 319 335 1753
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- **M.P. Gough**, (University of Sussex), Responsible for EGSE:

technical design, software, interfaces with experiment schedules.

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SPAN : to be confirmed (or used via JANET)

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- **A. Roux** (CRPE/CNET), chairman of the Scientific Board.

CNET / RPE same address as above
Telephone : [33 1] 45 29 44 15
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c) WECTCO Functional Organigramme

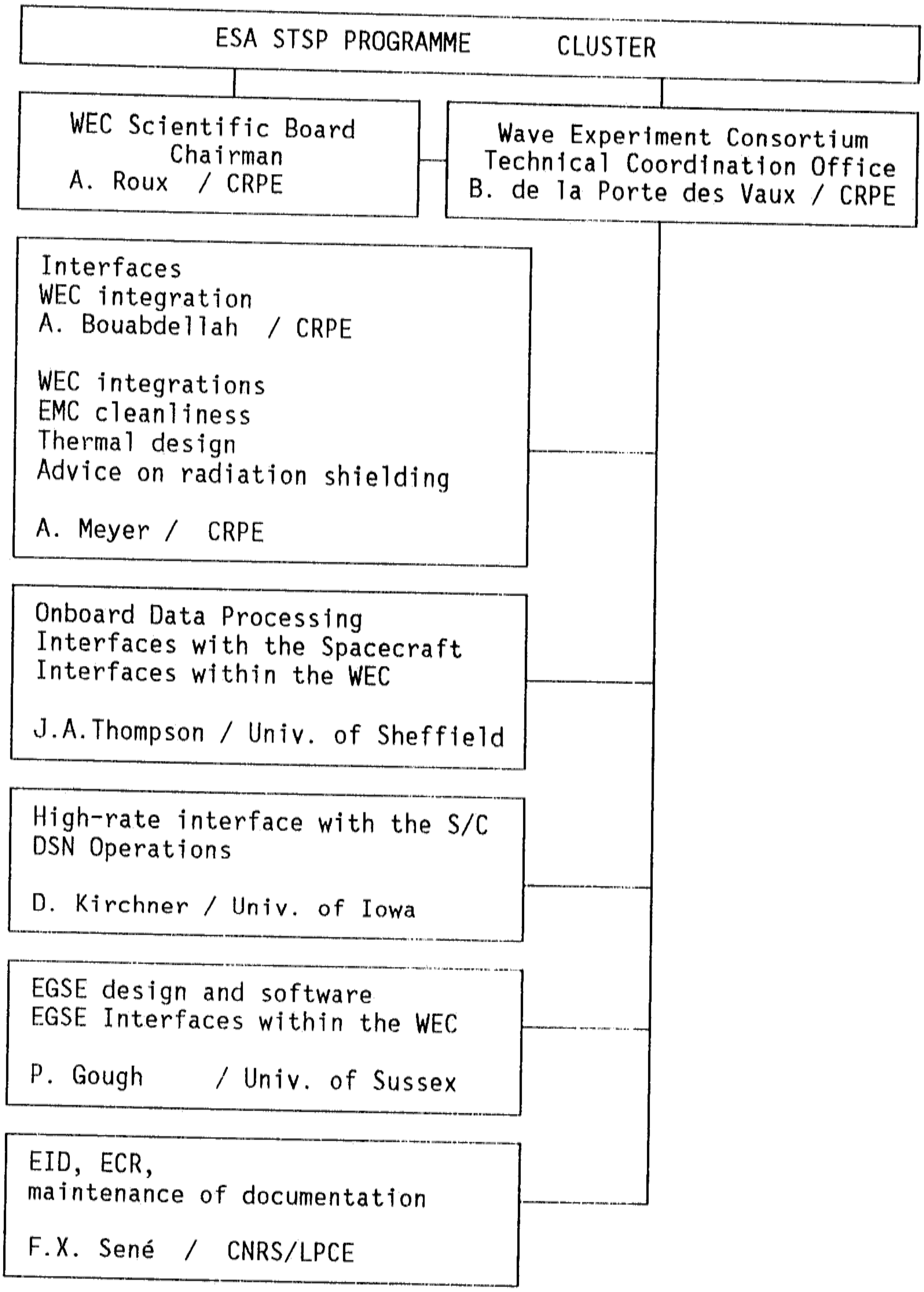

Fig 1.1/1.1 WECTCO functional organigramme

1.1.2 EFW Key personnel and Responsibilities

a) EFW Directory

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T. Aggson
R. Pfaff

The other members of the team will mainly participate in the Science Working Team to improve the scientific results of this experiment and also contribute to the development of the possible software for scientific analysis and finally in the interpretation of the data.

b) EFW Institute responsibility

Duty \ Institute	UCB	IRF-U	ESTEC	RIT	AFGL	Oulu	Oslo	CNET
Management		1						
S/W coord/data reduction		1		2			2	
BBM Instrument integration	1							
EM Instrument integration		2	2	2	2	2	2	
WEC level integration	2	1	2	2			2	
Spacecraft integration	2	2	1	2	2	2	2	
EGSE S/W	1	2		2	2	2	2	
EGSE S/W WEC			1					
MGSE							1	
Onboard S/W (µP)	1	2		2	2			
Probe preamplifiers	d	d	DF	d			d	
Probe surface			DF					
Probe bias circuit & deployment control	d	d	d	DF			d	
Filters, diff. amp. & I/F to other Exp.	d	D	dF	d			d	d
µP, S/H, ADC, MUX, MEM	D	d	F	d			d	
Box	d	d	DF	d	d	d	d	
Booms & boom mechanism & spherical sensors mechanical parts	DF					Df		
Power supply	DF							
Central electronic packaging			DF					
EGSE & instrument test equipment, sign. generator UCB bench test only	DF					d	DF	
Int. harness & connectors			D					
Ext. harness & connectors		D						

1 Main responsibility
D Prime responsible for design
F Prime responsible for fabrication
2 Secondary duty
d Secondary responsible for design
f Secondary responsible for fabrication
All participate in SWT and S/W development for scientific analysis

Tab 1.1/1.2 EFW institutes responsibilities

c) **EFW Functional Organigramme.**

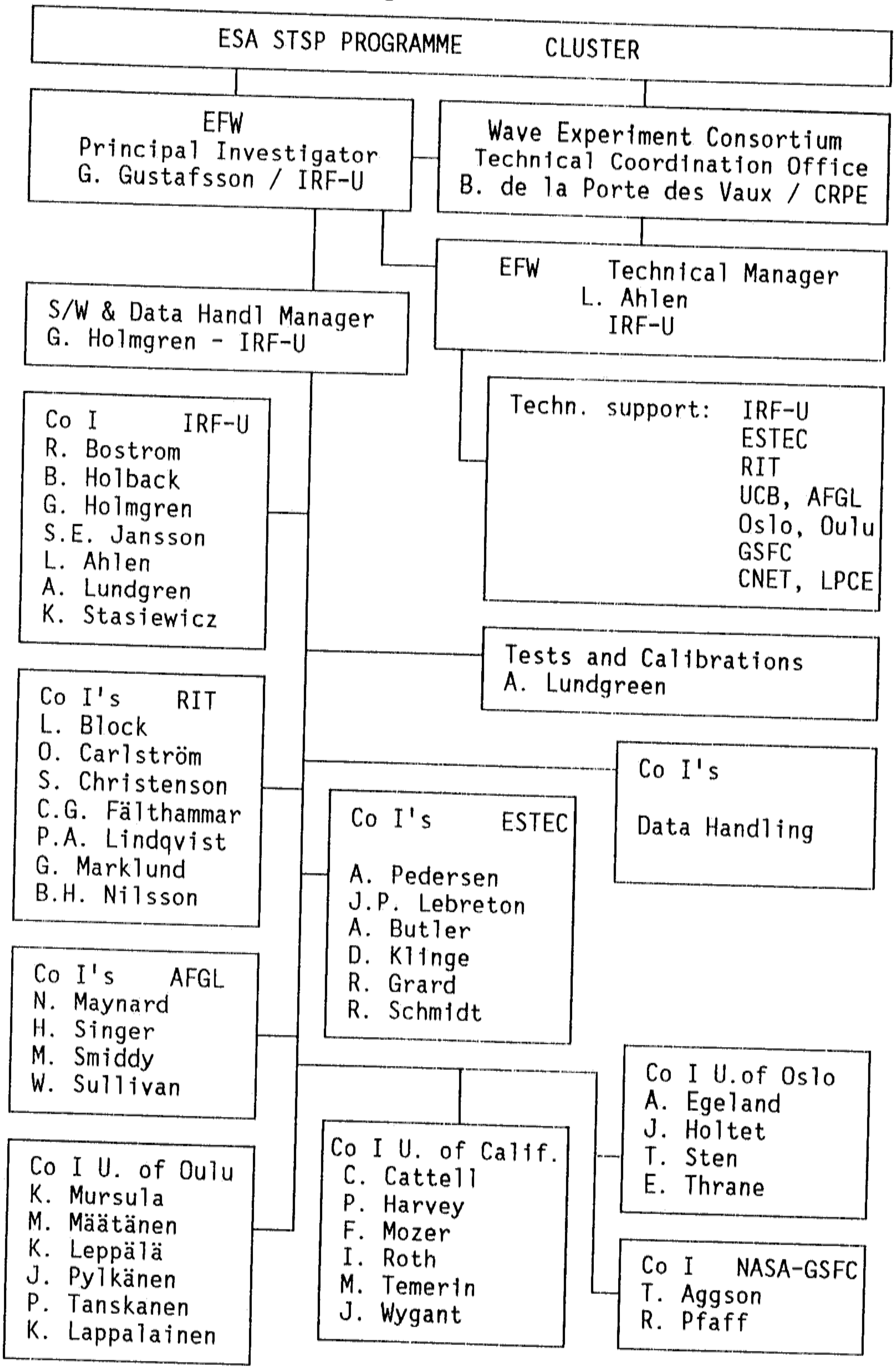


Fig 1.1/1.2 EFW functional organigramme

1.1.3 STAFF Key personnel and Responsibilities

a) STAFF Directory

C.R.P.E./C.N.E.T.
STAFF coordination; search coils, preamplifiers, waveform analysers
Address : 38-40 rue du Général Leclerc
92131 Issy-les-Moulineaux CEDEX
France
Telex : 200570 F CNETION
Telefax : [33 1] 45 29 60 52
SPAN : CRPEIS::name
EARN : [8 first characters of name]@FRCRPE51 (BITNET)

PI : **Nicole Cornilleau-Wehrlin**
Telephone : [33 1] 45 29 50 17 or 45 29 48 54
Home : [33 1] 46 45 68 37

Technical manager : **Alain Meyer**
Telephone : [33 1] 45 29 49 06 or 45 29 48 54

DESPA/Meudon Observatory
Spectrum analyser
Address : 5, Place Jules Janssen
92195 Meudon CEDEX
France
Telex : 204464 F DESPA
Telefax : [33 1] 45 07 28 06
SPAN : MEUDON::name
EARN : [8 first characters of name]@FRMEU51

Co-i : **Christopher Harvey**
Telephone : [33 1] 45 07 76 69

Lead engineer : **Robert Manning**
Telephone : [33 1] 45 07 76 86

LPCE-CNRS
Filters: design, check and calibration
Address : 3A, Avenue de la Recherche Scientifique
45071 Orléans-Cedex 2
France
Telex : 760600 F CNETORL
Telefax : [33] 38 63 12 34
SPAN : CRPEIS::name

Co-i : **Michel Parrot**
Telephone : [33] 38 51 52 91

Lead engineer : **Bernard Poirier**
Telephone : [33] 38 51 53 02

SSD-ESTEC
Manufacturing of filters
Address : P.O.Box 299
2200 AG-Noordwijk
The Netherlands
Telephone : [31] 17 19 8 35 94
Telex : 39135 or 39098 ESTEC NL
Telefax : [31] 17 19 1 74 00
SPAN : ESTCS1::APEDERSE

Co-i : Arne Pedersen

Lead engineer : A. Butler

CEPHAG-ENSIEG
Data Analysis
Address : Domaine universitaire
BP 46
38402 St Martin d'Heres - CEDEX
France
Telephone : [33] 76 82 62 63
Telex : 320 245 F

Co-i : W. Kofman

b) STAFF Tasks and Responsibilities

CRPE-CNET	- STAFF coordination (PI + technical manager) - manufacturing and testing of : search coil, wave-form unit, calibration - support to integration and testing - check-out software - data analysis
DESPA-Meudon	- Manufacturing and testing of the spectrum analyzer - support to integration and testing - check-out software - data analysis
LPCE-CNRS	- design, check and calibration of the filters (for both STAFF and EFW) - data analysis
SSD-ESTEC	- manufacturing of the filters
CEPHAG	- Theoretical support for signal analysis

Tab 1.1/1.3 STAFF institutes responsabilities

c) **STAFF Functional Organigramme.**

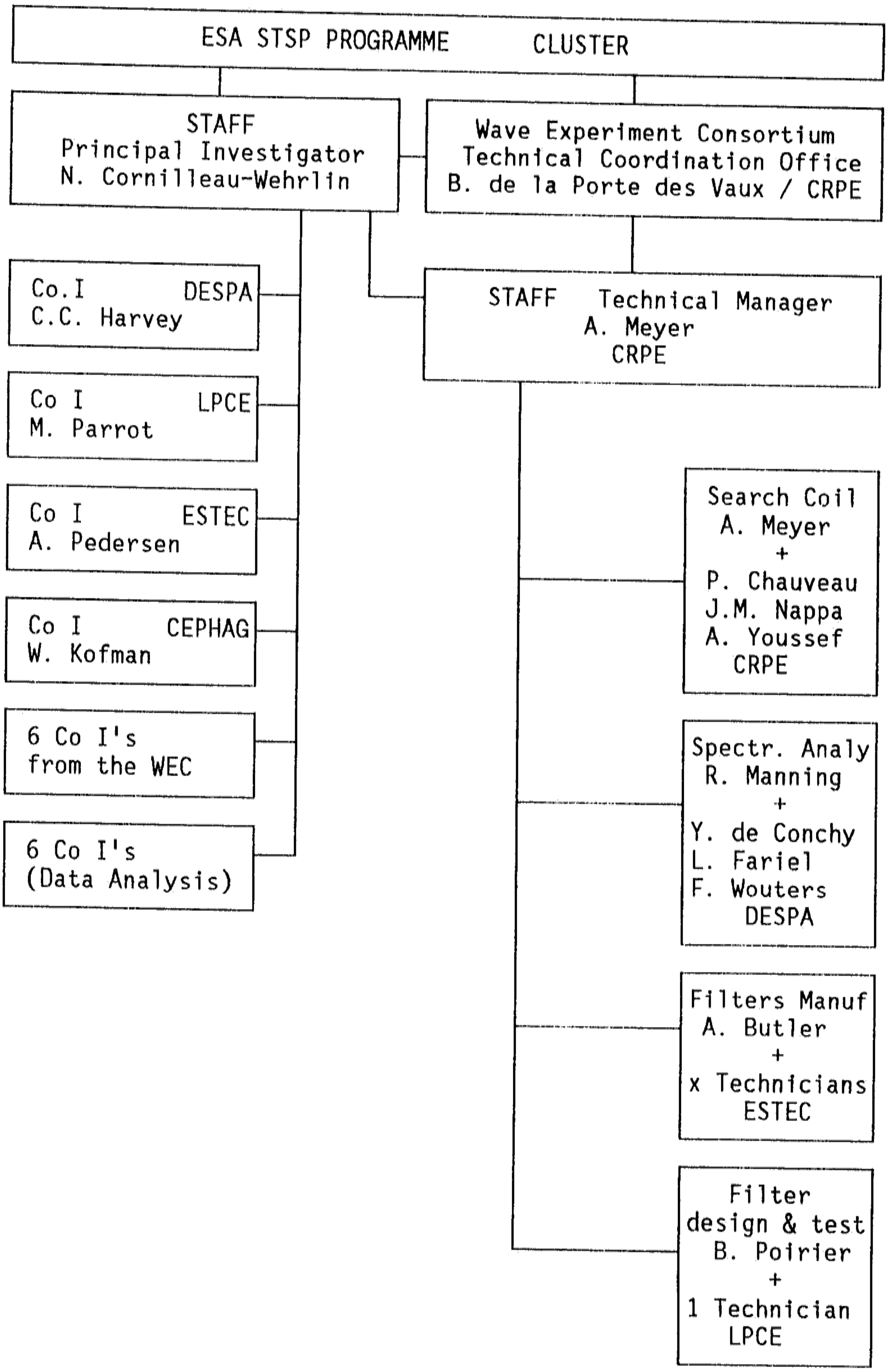


Fig 1.1/1.3 STAFF functional organigramme

1.1.4 WHISPER Key Personnel and Responsibilities

a) WHISPER Directory

Principal Investigator : P.M.E. Décréau
Institute : LPCE/CNRS
Laboratoire de Physique et Chimie de
l'Environnement
Address : 3A, Ave. de la Recherche Scientifique
45071 ORLEANS CEDEX 02 FRANCE
Telephone : [33] 38 51 52 81
Telex : 760600 F LPCEORL
Telefax : [33] 38 63 12 34
SPAN : CRPEIS::DECREAU

Technical Manager, PA and AIV : F.X. Sené
Institute : LPCE/CNRS
Laboratoire de Physique et Chimie de
l'Environnement
Address : 3A, Ave. de la Recherche Scientifique
45071 ORLEANS CEDEX 02 FRANCE
Telephone : [33] 38 51 52 77
Telex : 760600 F LPCEORL
Telefax : [33] 38 63 12 34
SPAN : CRPEIS::SENE

Technical Manager Deputy, DH, EMC and administration : Ph. Martin
Institute : LPCE/CNRS
Laboratoire de Physique et Chimie de
l'Environnement
Address : 3A, Ave. de la Recherche Scientifique
45071 ORLEANS CEDEX 02 FRANCE
Telephone : [33] 38 51 52 99
Telex : 760600 F LPCEORL
Telefax : [33] 38 63 12 34

Technical Manager Deputy : P.B. Mogensen
Institute : DSRI
Danish Space Research Institute
Address : Gl. Lundtoftevej 7
DK-2800 LYNGBY DENMARK
Telephone : [45] 42 88 22 77
Telex : 37198 DK DANRU
Telefax : [45] 45 93 02 83

Co Investigator and Telecommand : A. Bahnsen
Institute : DSRI
Danish Space Research Institute
Address : Gl. Lundtoftevej 7
DK-2800 LYNGBY DENMARK
Telephone : [45] 42 88 22 77
Telex : 37198 DK DANRU
Telefax : [45] 45 93 02 83

Co Investigator, Flight Operations and on-Board Software : P.Canu
Institute : CRPE/CNET
: Centre de Recherche en Physique de l'Environnement
Address : 38-40, Rue du Général Leclerc
92131 ISSY-LES-MOULINEAUX CEDEX FRANCE
Telephone : [33] 1 45 29 51 93
Telex : 200570 F CNETION
Telefax : [33] 1 45 29 60 52
SPAN : CRPEIS::CANU

Co Investigator, Ground Operations and Flight Cal.: I. Iversen
Institute : DSRI
Danish Space Research Institute
Address : Gl. Lundtoftevej 7
DK-2800 LYNGBY DENMARK
Telephone : [45] 42 88 22 77
Telex : 37198 DK DANRU
Telefax : [45] 45 93 02 83

Co Investigator and on-Board and Ground Software : J.G. Trotignon
Institute : LPCE/CNRS
Laboratoire de Physique et Chimie de
l'Environnement
Address : 3A, Ave. de la Recherche Scientifique
45071 ORLEANS CEDEX 02 FRANCE
Telephone : [33] 38 51 52 63
Telex : 760600 F LPCEORL
Telefax : [33] 38 63 12 34

Co Investigator : H. de Feraudy
Institute : CRPE/CNET
: Centre de Recherche en Physique de l'Environnement
Address : 38-40, Rue du Général Leclerc
92131 ISSY-LES-MOULINEAUX CEDEX FRANCE
Telephone : [33] 1 45 29 51 93
Telex : 200570 F CNETION
Telefax : [33] 1 45 29 60 52
SPAN : CRPEIS::CANU

Co Investigator : D.A. Gurnett
Institute : University of Iowa
Address : Department of Physics and Astronomy
Iowa City, IOWA 52242 U.S.A.
Telephone : [1] 319 335 1697
Telex : 910 525 1398
Telefax : [1] 319 335 1753
SPAN : IOWA::GURNETT

Co Investigator : G. Gustafsson
Institute : IRF-U
Swedish Institute of Space Physics
Address : Uppsala Division
S-755 91 Uppsala Sweden
Telephone : [46] 18 30 36 11
Telex : 76036 S UJONUS
Telefax : [46] 18 40 31 00
SPAN : PLAFYS::GUSTAFSSON or uucp:gg@irfu.se

Co Investigator : M. Jespersen
Institute : DSRI
Danish Space Research Institute
Address : Gl. Lundtoftevej 7
DK-2800 LYNGBY DENMARK
Telephone : [45] 42 88 22 77
Telex : 37198 DK DANRU
Telefax : [45] 45 93 02 83

Co Investigator : L.J.C. Woolliscroft
Institute : The University of Sheffield
Address : Department of Physics
Sheffield S3 7RH ENGLAND
Telephone : [44] 742 768 555 Ext. 4354
Telex : 547216 UGSHEF
Telefax : [44] 742 739 826
SPAN : RLVK::LJCW

Technical Manager, Prime Contractor : J.P. Olivo
Institute : Ets AETA
Applications Electronique
Techniques Avancées
Address : 62-70 Rue Blanchard
92260 FONTENAY AUX ROSES FRANCE
Telephone : [33] 1 46 61 22 55
Telex : 632170 F
Telefax : [33] 1 46 61 32 70

b) WHISPER Tasks and Responsibilities

PI : Principal Investigator
TM : Technical Manager
DH : Design Hardware
FO : Flight Operations
BS : on-Board Software (implemented in the DWP for WHISPER)
GO : Ground Operations (data reception at the G/S)
GS : Ground Software (EGSE software and treatment of final data)
FC : in Flight Calibration (definition and maintenance)
TC : Telecommand
EM : EMC (Electromagnetic Compatibility)
AI : AIV (Assembly Integration verification)
PA : Product Assurance
AD : Administration (schedule, meeting attendance organisation...)

1 : Prime Responsibility
2 : Secondary duty

NAME \ TASK	PI	TM	DH	FO	BS	GO	GS	FC	TC	EM	AI	PA	AD
A. Bahnsen				2					2		2		
P. Canu				1	1		2	2					
H. de Feraudy				2	2	2	2						
I. Iversen				2	2	1		1	1		2		
M. Jespersen													2
Ph. Martin		2	1							1		2	1
P.B. Mogensen		2	1							2	2	2	
P.M.E. Décréau	1							2		2			2
F.X. Sené		1	2							2	1	1	
J.G. Trotignon					1		1		2				
L. Woolliscroft					2		2						

WHISPER Institute prime responsibility sharing

INSTITUTE\TASK	PI	TM	DH	FO	BS	GO	GS	FC	TC	EM	AI	PA	AD
L.P.C.E.	X	X	X		X		X			X	X	X	X
D.S.R.I.			X			X		X	X				
C.R.P.E.				X	X								

Tab 1.1/1.4 WHISPER institutes responsibilities

c) WHISPER Functional Organigramme

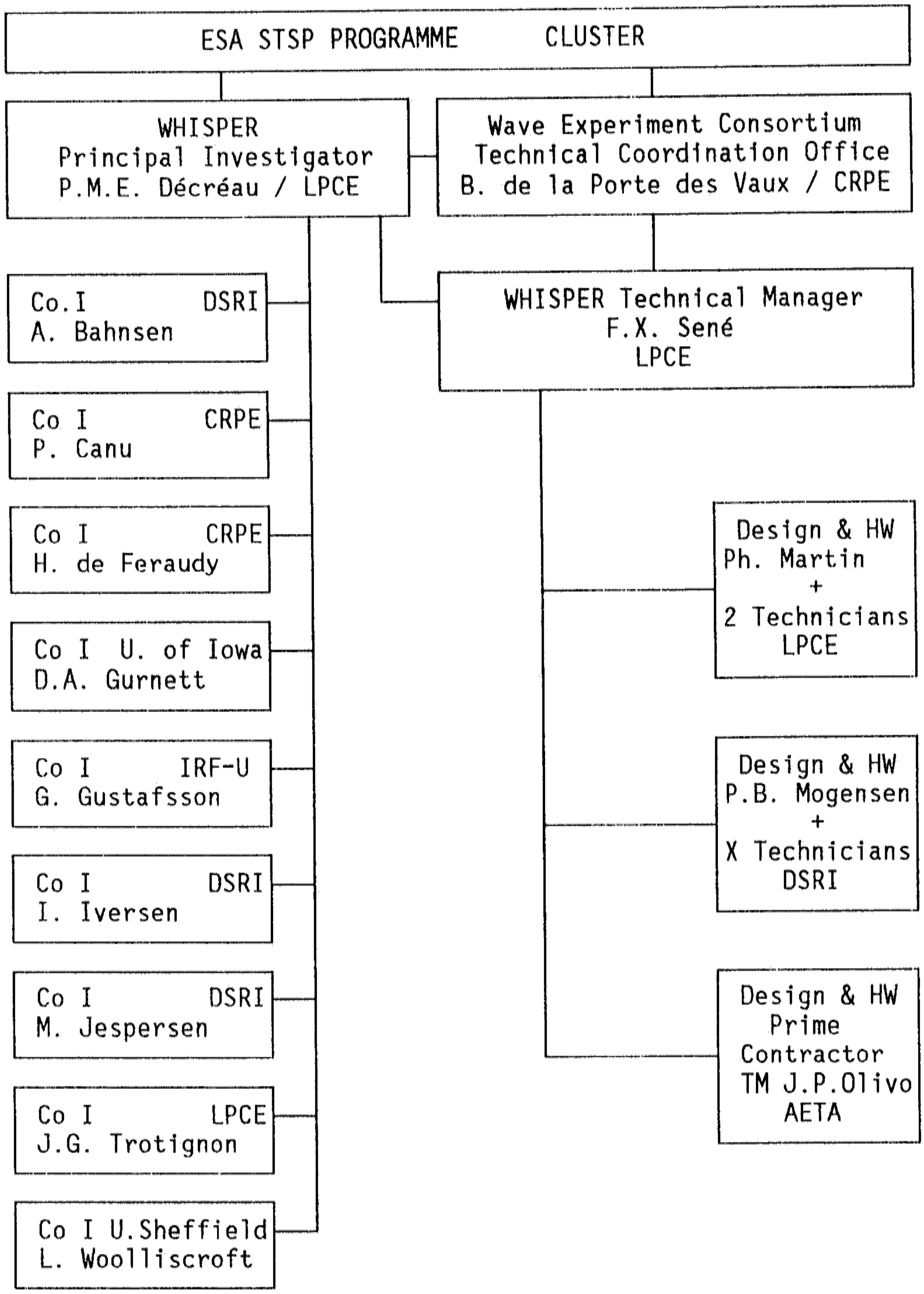


Fig 1.1/1.4 WHISPER functional organigramme

1.1.5 WBD Key Personnel and Responsibilities

a) WBD Directory

Principal Investigator : Donald A. Gurnett

Department of Physics and Astronomy
The University of Iowa
Address : Iowa City, IA 52242
USA
Telephone : [1] 319 335 1697
Secretary : [1] 319 335 1696
Home : [1] 319 338 4738
Telex : 910 525 1398
Telefax : [1] 319 335 1753
SPAN : IOWASP::GURNETT
NASAMAIL : DGURNETT

Richard L. Huff, Project Manager
Same address
Telephone : [1] 319 335 1934
Secretary : [1] 319 335 1698
Home : [1] 319 645 2601
SPAN : IOWASP::HUFF

Donald L. Kirchner, Lead Engineer
same address
Telephone : [1] 319 335 1958
Secretary : [1] 319 335 1698
Home : [1] 319 338 7300
SPAN : IOWASP::KIRCHNER

b) WBD Tasks and Responsibilities

All tasks are under responsibility of IOWA University

c) WBD Functional Organigramme.

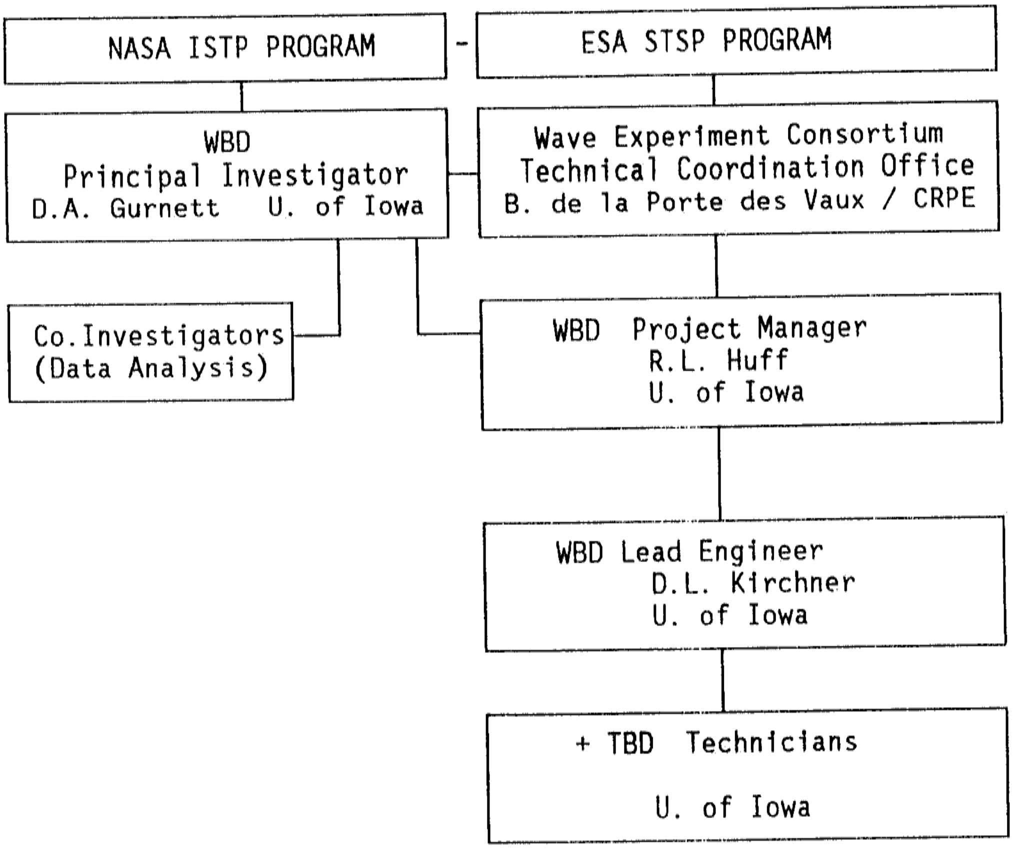


Fig 1.1/1.5 WBD functional organigramme

1.1.6 DWP Key Personnel and Responsibilities

a) DWP Directory

Principal Investigator : L.J.C. Woolliscroft
University of Sheffield
Department of Automatic Control & Systems Engineering
Address : Sheffield S1 3JD
United Kingdom
Telephone : [44] 742 768555 ext 5137
Telex : 547216 UGSHEF G
Telefax : [44] 742 731729
SPAN : RLESIS::LJCW
RLVK::LJCW
RLVK::JANET%UK.AC.SHEFFIELD.PRIMEA::PH1LJW

Technical Manager and COI : J.A. Thompson
University of Sheffield
Department of Computer Science
same address
Telephone : [44] 742 768555 ext 5581
Telex : 547216 UGSHEF G
Telefax : [44] 742 739826
SPAN : RLVK::JANET%UK.AC.SHEFFIELD.PRIMEA::PH1JAT

Project Manager : H. St. C. Alleyne
University of Sheffield
Department of Physics
address : Sheffield S3 7RH
Telephone : [44] 742 768555 ext 4354
Telex : 547216 UGSHEF G
Telefax : [44] 742 728079
SPAN : RLVK::JANET%UK.AC.SHEFFIELD.PRIMEA::PH1HA

Co Investigator and EGSE : P. Gough
University of Sussex / EAPS
Address : Falmer, Brighton
East Sussex BN1 9QT
United Kingdom
Telephone : [44] 273 678 421
Telex : 878 358 ENGINE G
Telefax : [44] 273 678 399
SPAN : RLVK::JANET%UK.AC.SUSSEX.CLUSTER::TAFI6

Co-ordinator of EGSE : P. Davies
University of Sussex / EAPS
Address : Falmer, Brighton
East Sussex BN1 9QT
United Kingdom
Telephone : [44] 273 606 755
Telex : 878 358 ENGINE G
Telefax : [44] 273 678 399
SPAN : RLVK::JANET%UK.AC.SUSSEX.CLUSTER::TAFL3

b) DWP Tasks and Responsibilities

INSTITUTE	RESPONSIBILITIES
University of Sheffield	- Management - Product Assurance - Design and procurement of DWP unit - Data analysis
University of Sussex	- E.G.S.E. (overall and European) - Check-out software - Data analysis

Tab 1.1/1.6 DWP institutes responsibilities

c) DWP Functional Organigramme.

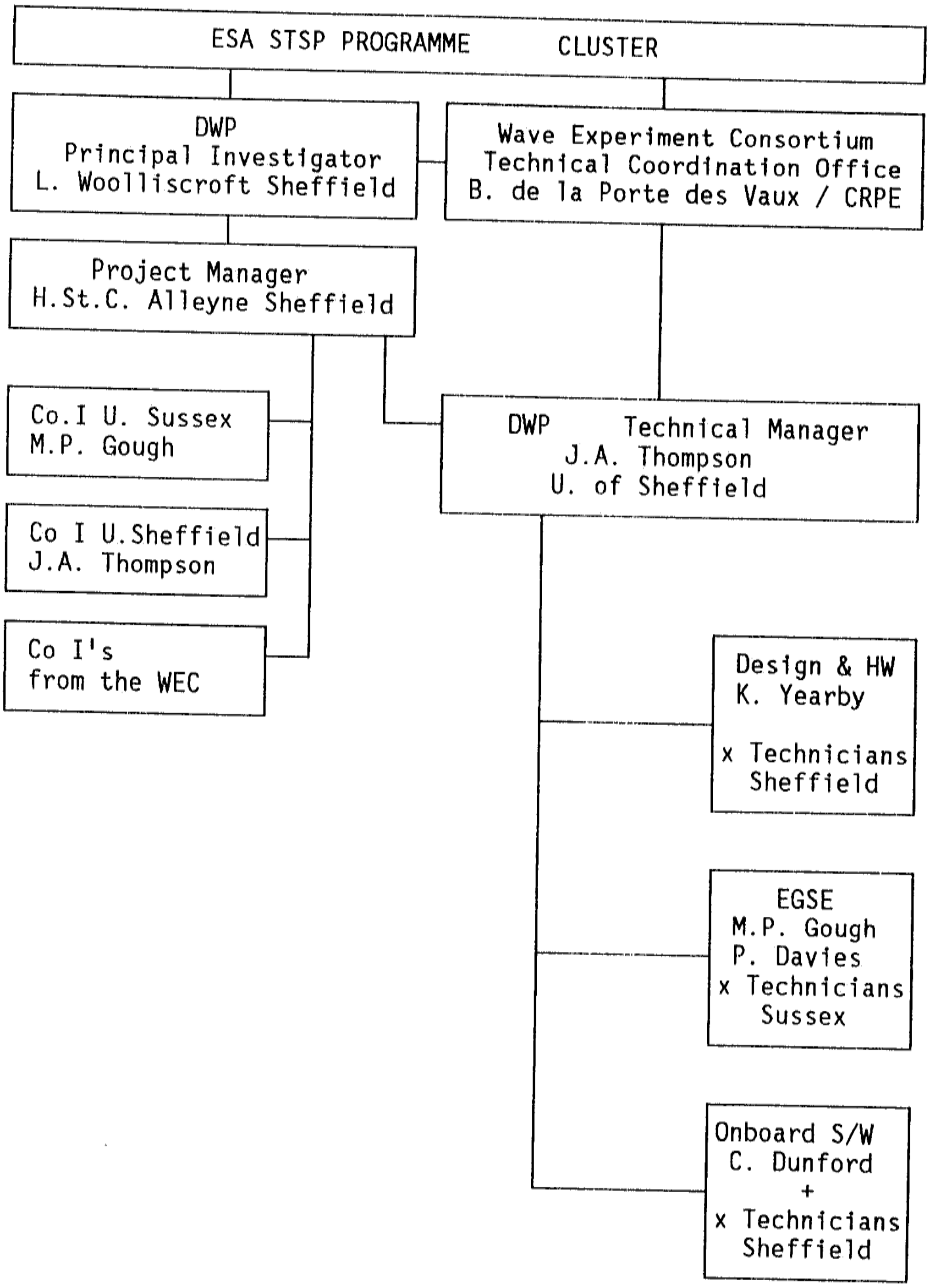


Fig 1.1/1.6 DWP functional organigramme

1.1.7 PWR Key Personnel and Responsabilities

a) PWR Directory

The Power Supply unit is under the responsibility of the **WECTCO** with a supervision of the University of Sheffield.

main responsibility: **B. de la Porte**
support : **L. Woolliscroft**
lead engineer : **A. Meyer**

b) PWR Tasks and Responsibilities

The cost of the Power Supply is shared within **STAFF, WHISPER** and **DWP**. The **WECTCO** (CRPE) and the University of Sheffield have the technical responsibility of the unit which will be manufactured in a French industry.

c) PWR Functional Organigramme

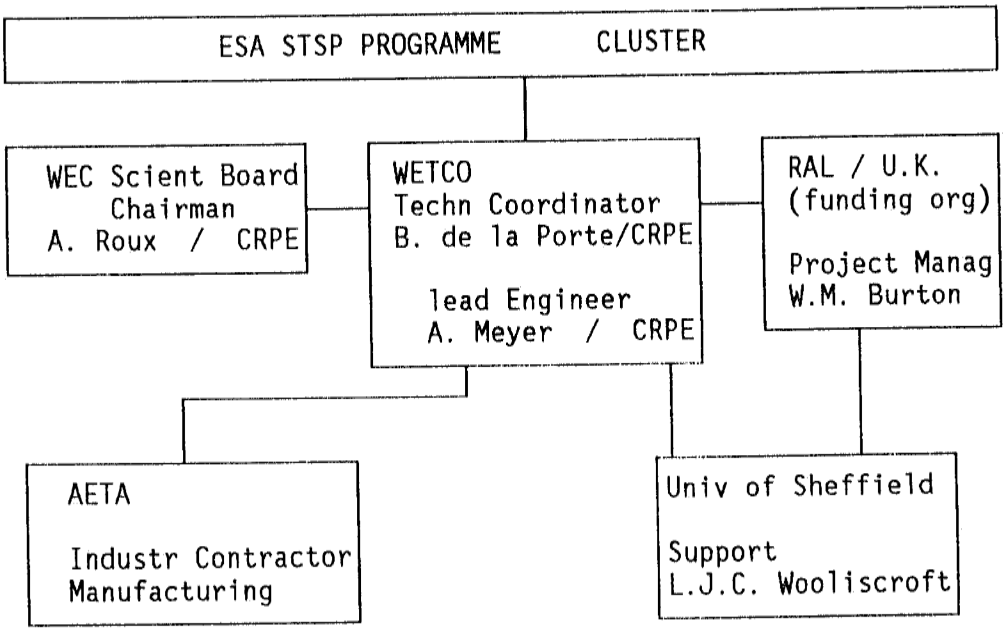


Fig 1.1/1.7 PWR functional organigramme

1.2 BRIEF EXPERIMENT DESCRIPTION.

1.2.1 Scientific objectives of the WEC

The interaction between the solar wind and the Earth's magnetic field leads to the formation of critical layers, or discontinuities, with a thickness which is much smaller than the mean free path between binary particle collisions. The existence of these critical layers implies a dissipation that classical collisions cannot generate. Hence, the dissipation, the thermalization which is required, must be effected via "anomalous" processes, that is to say by plasma turbulence. The main purpose of the investigation which will be carried out by the Wave Experiment Consortium (WEC) is the analysis of plasma turbulence with appropriate means and the assessment of its role, within these critical layers. In addition to that, the WEC instruments will give access to key macroscopic parameters such as the total density of the plasma and the quasistatic electric field, to their spatial/temporal variations, and to the quantities which can be derived from their spatial variations. To be more specific, the goals of the study which will be conducted by the WEC are :

(i) Characterisation of time domain (electrostatic) small scale structures, such as weak double layers or electrostatic shocks.

(ii) Unambiguous determination of the shape, velocity and current density of small scale field aligned current (electro-magnetic) structures.

(iii) Assessment of the role played by low frequency (e.g. ion cyclotron, lower hybrid,....) and high frequency (e.g. upper hybrid...) waves in the "anomalous" behaviour of the plasma within critical layers.

(iv) Investigation of the role played by plasma waves and turbulence in accelerating electrons along magnetic field lines.

(v) Determination of the location of the sources of waves.

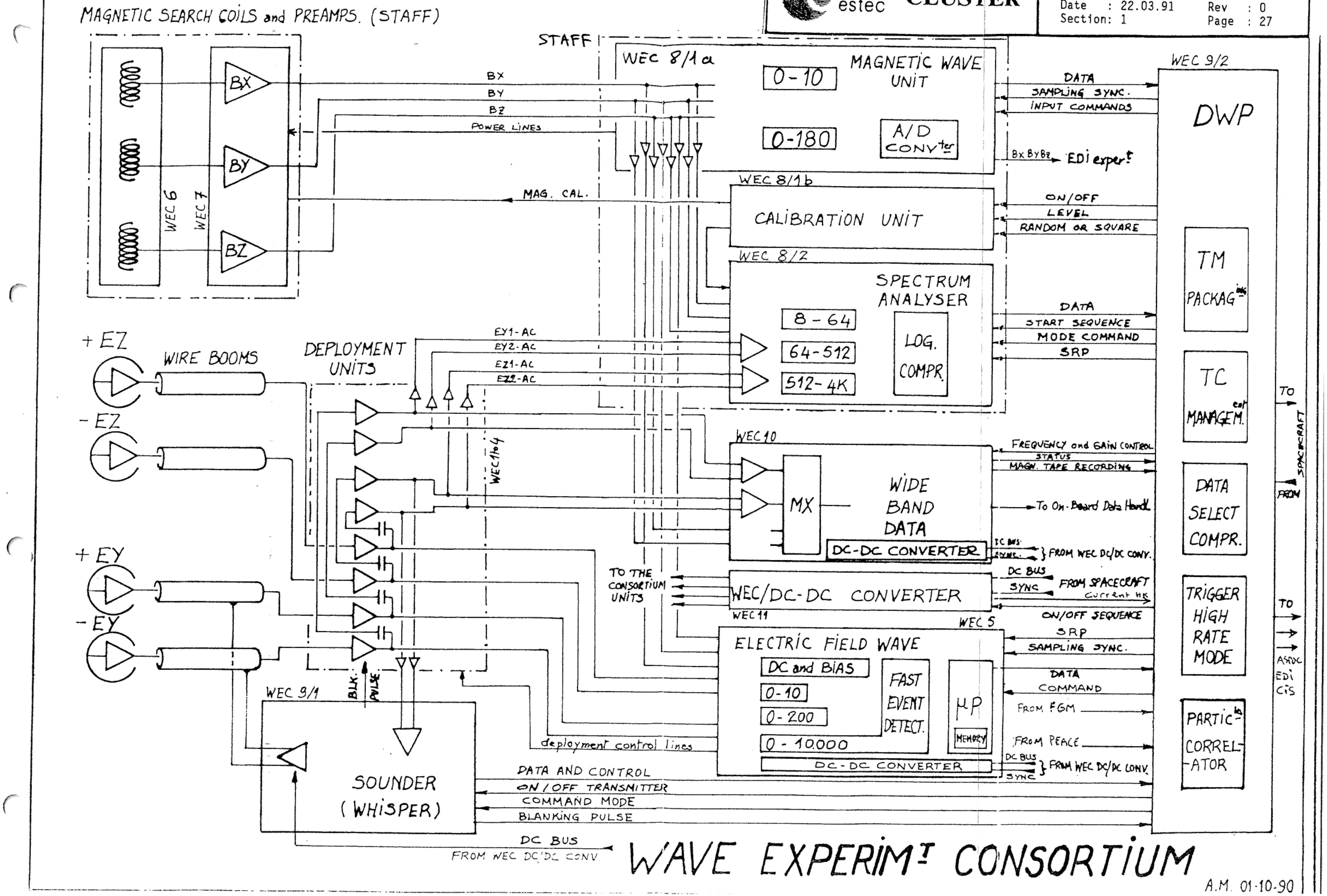
(vi) Investigation of the fine structure of high frequency waves and of its consequences on nonlinear wave-particle interactions.

(vii) Measurement of the vector electric field and its fluctuations, in the spin plane.

(viii) Measurement of the plasma density and its fluctuations.

(ix) Evaluation of the vorticity, the current density magnetic helicity, via spatial derivatives of the macroscopic parameters.

(x) Evaluation of the spacecraft potential.


MAGNETIC SEARCH COILS and PREAMPS. (STAFF)
BX
BY
BZ
WEC 6
WEC 7
STAFF
WEC 8/1a
MAGNETIC WAVE UNIT
0-10
0-180
A/D CONVter
POWER LINES
MAG. CAL.
WEC 8/1b
CALIBRATION UNIT
WEC 8/2
SPECTRUM ANALYSER
8 - 64
64-512
512-4K
LOG. COMPR.
+EZ
-EZ
+EY
-EY
WIRE BOOMS
DEPLOYMENT UNITS
EY1-AC
EY2-AC
EZ1-AC
EZ2-AC
WEC 1 to 4
WEC 10
MX
WIDE BAND DATA
DC-DC CONVERTER
TO THE CONSORTIUM UNITS
WEC/DC-DC CONVERTER
WEC 11
WEC 5
ELECTRIC FIELD WAVE
DC and BIAS
0-10
0-200
0-10000
FAST EVENT DETECT.
μP
MEMORY
DC-DC CONVERTER
WEC 9/1
BLK.
PULSE
SOUNDER (WHISPER)
deployment control lines
DATA AND CONTROL
ON/OFF TRANSMITTER
COMMAND MODE
BLANKING PULSE
DC BUS
FROM WEC DC/DC CONV
WEC 9/2
DWP
DATA
SAMPLING SYNC.
INPUT COMMANDS
Bx By Bz
EDI expert
ON/OFF
LEVEL
RANDOM OR SQUARE
DATA
START SEQUENCE
MODE COMMAND
SRP
FREQUENCY and GAIN CONTROL
STATUS
MAGN. TAPE RECORDING
To On-Board Data Handl.
TC BUS
SYNC
FROM WEC DC/DC CONV.
DC BUS
SYNC
FROM SPACECRAFT
Current HK
ON/OFF SEQUENCE
SRP
SAMPLING SYNC.
DATA
COMMAND
FROM FGM
FROM PEACE
DC BUS
SYNC
FROM WEC DC/DC CONV.
TM PACKAGing
TC MANAGEMent
DATA SELECT COMPR.
TRIGGER HIGH RATE MODE
PARTICle CORREL-ATOR
TO
FROM
SPACECRAFT
TO
ASPOC
EDI
CIS
WAVE EXPERIMt CONSORTIUM
A.M. 01-10-90

1.2.2 Hardware Functional Description

For the achievement of the scientific objectives with a good optimisation of the technical resources, five coordinated experiments have been proposed and selected. The different elements of the Wave Experiment Consortium (WEC) are shown on the general block diagram Fig. 1.2/1. A Brief Experiment Description of each experiment is given below :

1.2.2.1 EFW Brief Experiment Description

The electric field and wave experiment (EFW) on Cluster is designed to measure the electric field and density fluctuations with sampling rates, on some occasions, up to 36000 samples/s in two channels. Langmuir sweeps can also be made to determine the electron density and temperature. Among the more interesting objectives of the experiment is to study nonlinear processes that result in acceleration of plasma. Large scale phenomena where all four spacecraft are needed will also be studied.

To meet the scientific objectives the electric field instrument will be capable of measuring, in various modes;

- Instantaneous spin plane components of the electric field vector, over a dynamic range of 0.1 to 700 mV/m, and with variable time resolution down to 0.1 ms.

- The low energy plasma density, over a dynamic range at least 1 to 100 cm^{-3};

- Electric fields and density fluctuations of small amplitude in double layers, over dynamic ranges of 0.1 to 50 mV/m for the fields and 1 to 50 percent for the relative density fluctuations, and with a time resolution of 0.1 ms on some occasions;

- Electric fields and density fluctuations in electrostatic shocks or double layers of large amplitude, over dynamic ranges of 0.1 to 700 mV/m for the fields and 1 to 50 percent for the relative density fluctuations, and with a time resolution of 0.1 ms on some occasions;

- Waves, ranging from electrostatic ion cyclotron emissions having amplitudes as large as 60 mV/m at frequencies as low as 50 millihertz, to lower hybrid emissions at several hundred Hertz and with amplitudes as small as a few microV/m;

- Time delays between signals from up to four different antenna elements on the same spacecraft, with a time resolution of 25 microseconds on some occasions.

- The spacecraft potential.

The detector of the instrument consists of four orthogonal spherical sensors deployed from 50 meter cables in the spin plane of the spacecraft, four deployment units, and a separate main electronics unit as shown in the block diagram in Figure 1.2/2.1. The instrument has several important features. The potential drop between two opposing spherical sensors can be measured to provide an electric field measurement. The instrument can also be operated as a Langmuir Probe and biased to provide the Langmuir current-voltage curve and, thus, the electron temperature and density. The potentials of the spherical sensor and nearby conductors are controlled by the microprocessor in order to minimise errors associated with photoelectron fluxes to and from the spheres. The output signals from the spherical sensor preamplifiers are provided to the wave instruments for analysis of high frequency wave phenomena. The instrument has a 1-megabyte burst memory and two fast A/D conversion circuits for recording electric field wave forms for time resolutions up to 10 kHz. Data gathered in the burst memory will be played back through the telemetry stream allocated to the electric field experiment by pre-empting a portion of the real time data gathered by the instrument.On board calculations of least square fits to the electric field data over one spacecraft spin period (4 seconds) will provide a baseline of high quality two dimensional electric field components that are always present in the telemetry stream. Incoming data is continuously monitored using algorithms in software to determine if conditions are appropriate for triggering a burst collection playback.

Analog Electronics

Each sphere houses a preamplifier which measures the potential difference between the sphere surface and the spacecraft analog ground. Since the plasma has high source impedance (10^7 to 10^{10} ohms) and a capacitance of 5 picofarads due to the 8 cm diameter sphere, the preamplifier must have a low leakage current (<10 picoamperes) and low input capacitance (<1 picofarad) to avoid the attenuation of input signals. Since the potential of a biased sphere can differ from that of the spacecraft by 5-50 volts in the absence of an electric field, and fields as large as 500 mV/m have been observed, the dynamic range of the preamplifier and associated sensor electronics is +-70 volts from DC to 300 Hz. The small signal response exists to 600 kHz for use by the AC electric field instrument.

The 50-meter boom cable between the deployment unit and the sphere sensors contains eight wires and one coaxial cable. These wires carry the power to the preamplifier in the sphere, the biasing voltages on the stub and guard surfaces, and the biasing voltage to the bias resistor. The wires and coaxial cable are surrounded by a kevlar braid which provides mechanical support against the centrifugal stresses on the cable. The outer surface of the cable is a conductor which is tied via the Whisper transmitter transformer for +/- Ey with a resistor of 1 MOhms in parallel and via a short circuit plug for +/- EZ, to the EFW analog ground.

In order to limit and control the flux of photo-electrons from the booms to the spherical sensors and minimise error sources in the potentials of stub and guard surfaces are forced to follow the potential of the sphere with an adjustable DC offset. The DC offset is determined by 8 bit microprocessor-controlled digital-to-analog converters located in the digital section of the main electronics box. The stub voltage follows the sphere voltage with an offset which can range between -1.44 and +1.44 volts in 256 steps. The guard voltage follows the sphere potential with an offset between -35.6 and +35.6 volts in 256 steps.

The sphere potential is determined by the balance of plasma thermal currents, photoemission current, and a bias current to the sphere whose magnitude is controlled by on-board electronics to minimise the sheath impedance. This is accomplished by controlling the potential drop across a 75 Mohms bias resistor with bias control circuitry (see Figure 1.2/2.1). One end of the bias resistor is tied to the sphere surface. The other end of the resistor is driven by the bias control circuitry which operates in one of the two modes as determined by the state of a bias relay. If the instrument is measuring electric fields, the relay is set so that the bias control circuit follows the output of the sphere with a DC offset determined by the DAC. The potential drop across the resistor is the DAC determined value and the injected current is this value divided by the value of the resistance. This current can vary from -3.6 to +3.6 microamperes in 256 steps. These values are large enough to balance the maximum possible photoelectron flux from the spheres.

The spherical sensors can also be operated as current collecting Langmuir probes to provide information on the plasma density and electron temperature. In this mode, relays in each of the four deployment units are flipped so that the microprocessor controlled bias circuits are referenced to the satellite rather than the output of the sphere preamplifier.

The output of each sphere preamplifier is filtered by anti-aliasing filters with frequencies at 10 Hz, 180 Hz, 4 kHz and 8 kHz. A simple frequency counter is included for the range 5-250 kHz. The low frequency filter data will be utilised for direct transmission of data. The 180 Hz signal will be stored on the on-board tape recorder. The highest frequency data will be recorded in the internal burst memory and played out at slower telemetry rates.

Digital Electronics

The digital electronics contain two very fast analog-to-digital system, a set of digital-to-analog converters for biasing, a single 8-bit radiation-hard microprocessor, and a large burst memory. Extensive software functions increase the instrument's capabilities and data coverage.

The strategy for measuring the sphere voltages over a range of +- 700 mV/m to an accuracy of 1 microV/m can be achieved in a number of ways. With a 16-bit converter, the single ended measurements of sphere voltage (V1 through V4) will be measurable from 350 mV/m to 10 µV/m. Differential measurements V1-V2 and V3-V4 will have a gain factor of ten and thus be measurable to about 1 microV/m but will only have a range up to 10 mV/m.

Boom Deployment Mechanism

Each DC Electric Fields Deployment Unit is a small, self-contained package containing a motor driven mechanism that deploys a multiconductor cable and tip mounted spherical sensor in the spin plane of the Cluster satellites. On orbit, each opposing pair of cables will be symmetrically deployed to a tip-to-tip distance of approximately 100 meters. The assembly consists of two major components: a deployment mechanism, and the cable with sensor. The mechanism design has evolved from a series of successful satellite experiments including S3-2, S3-3, ISEE, Viking, and CRRES.

The deployment unit contains a rotating cable spool assembly, a brush DC gearmotor, an over-tension and end-of-cable indicator, an analog cable length indicator, a pyrotechnic-released spherical sensor housing, and a cable oscillation Coulomb damper through which the cable exits the mechanism.

Measured quantities

Three main parameters will be measured.
- The quasi static Electric Field.
- The Wave Electric Fields
- The plasma Density and the relative Density Fluctuations

Measured quantity	Frequency range	Dynamic range
DC Electric Field	0 - 10 Hz	700 mV/m - 0.1 mV/m
(2 components)	0 - 180 Hz	700 mV/m - 0.1 mV/m
	0 - 4000 Hz	700 mV/m - 0.1 mV/m
	0 - 32000 Hz	700 mV/m - 0.1 mV/m
AC Electric Field	10 - 8000 Hz	10 mV/m - 1 microV/m
(2 components)		See note.
Plasma density	0 - 10 Hz	1 - 100 cm^{-3}
fluctuations	0 - 180 Hz	1 - 100 cm^{-3}
	0 - 4000 Hz	1 - 100 cm^{-3}

Density and Temperature (Langmuir sweeps)	1 - 100 cm^{-3}, eV range

Note: For gain = 10. Final gain not yet determined.

Data rates

Nominal telemetry rate	1440 bits/sec
Tape Loading Mode Data Rate	15.1, 22.5, 29.4 kbit/sec
Burst Memory Loading Mode Data Rate	1152 kbit/sec

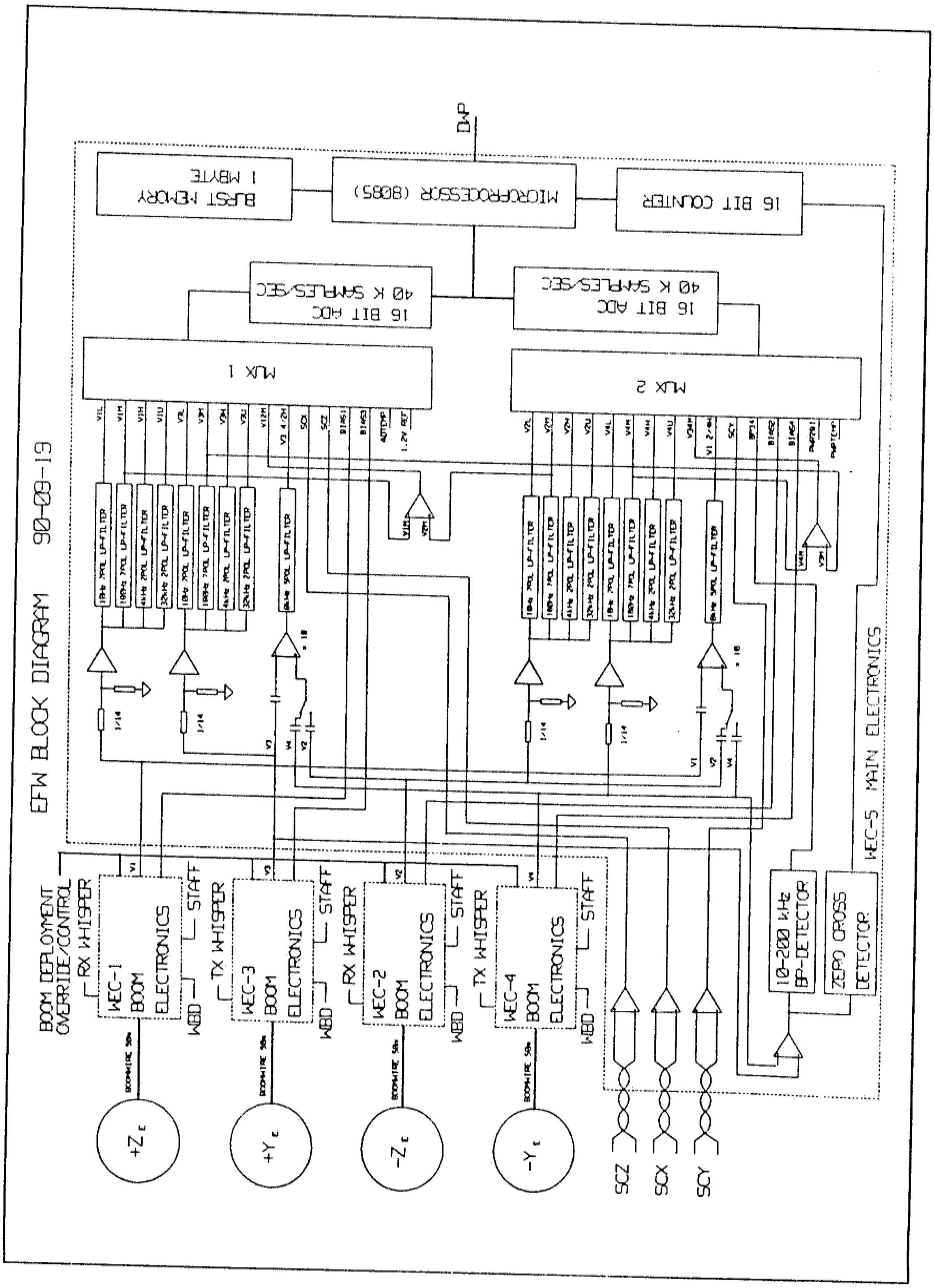


Fig: 1.2/2.1.a Block diagram of EFW

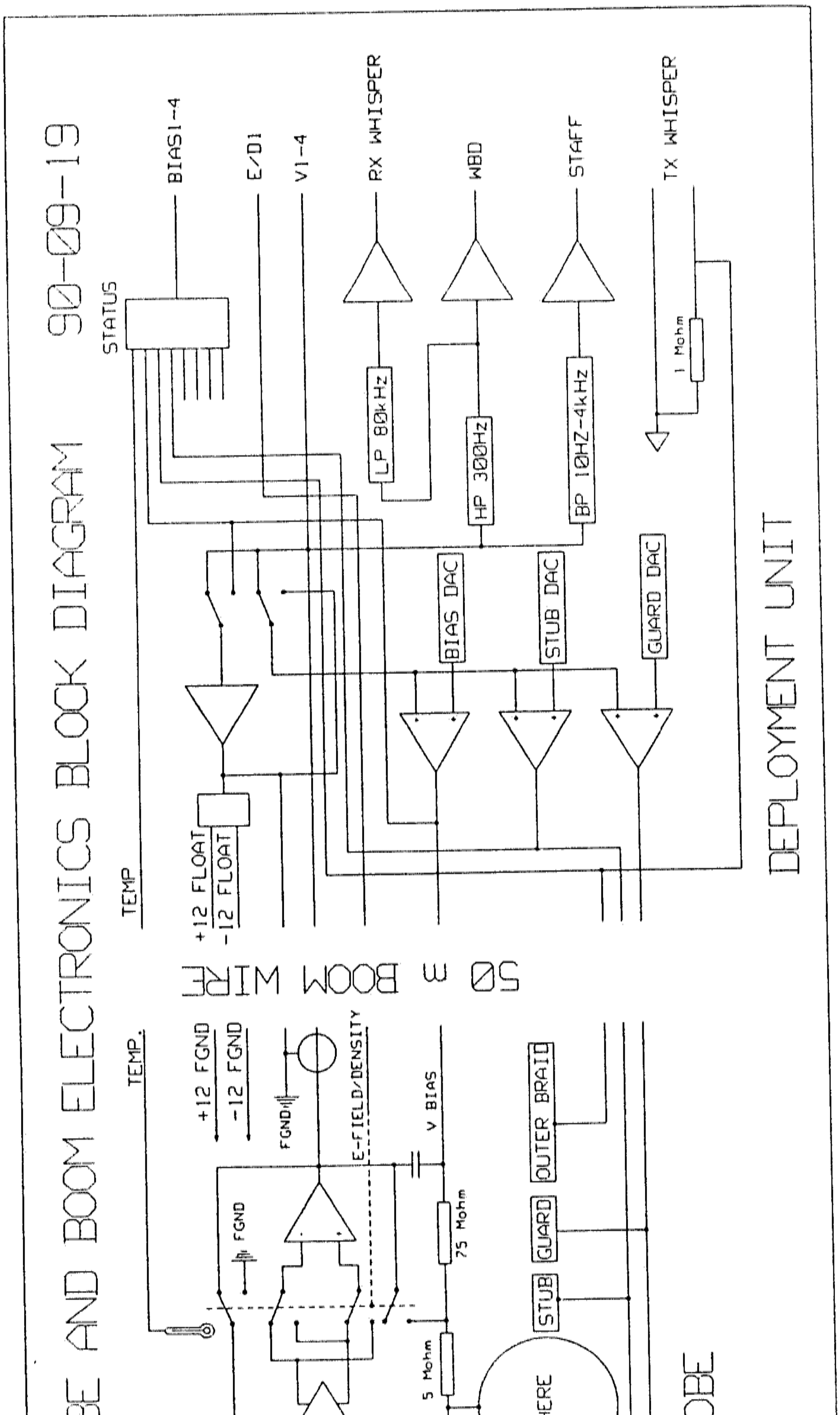


Fig: 1.2/2.1.b Block diagram of EFW

1.2.2.2 STAFF Brief Experiment Description

The STAFF experiment comprises two main parts, the measurement of the magnetic components of the waves up to 4 kHz by means of three orthogonal search coil sensors, and onboard data handling, which consists in transmitting the 3 magnetic wave forms up to either 10 Hz or 180 Hz on the one hand, and the calculation of the 25 coefficients of the spectral matrix (2 x E + 3 x B) up to 4 kHz on the other hand.

a) The search coil sensors and the preamplifiers

The search coil experiment will measure the low frequency magnetic fluctuations in a frequency range above that covered by the fluxgate experiment.

The three orthogonal sensors are mounted on a rigid boom away from the spacecraft body. Two sensors are in the spin plane, while the third one is parallel to the spacecraft spin axis (WEC 6 box). In order to ensure a good stability of the output signal, the magnetic search coil design includes a secondary winding which allows flux feedback. Each sensor consists of a high permeability core embedded inside two solenoids. The main winding has a very large number of turns, its resonant frequency is within the expected 3 dB bandwidth. The frequency response of the main winding is flattened by a secondary winding through a flux feedback effect, in the frequency range 40-4000 Hz. The main characteristics of the receiver are given in Figure 1.2/2.2.a. Furthermore, the secondary winding is used as a calibration loop where an external ac signal is applied through a calibration network included in the preamplifiers. Each search coil is connected to its preamplifier through a cable, the length of which should not exceed about 6 m with a low distributed capacitance (70 pF/m) (WEC 7/c).

The three preamplifiers are mounted in an electrical unit (WEC 7), located on the spacecraft deck. The low power consumption preamplifiers have a low noise input stage and high input impedance (10^8 - 10^{10} ohms) since they are connected to the magnetic sensors which are characterised by a low DC resistance and a very high source impedance in the vicinity of the resonant frequency. The dynamic range of the preamplifiers is about 100 dB, which allows them to withstand the large voltage signals induced by the spacecraft rotation in the DC magnetic field, as well as the weak signals to be measured, in particular in the highest frequency range covered (4 kHz).

The output signals of the magnetic preamplifiers are provided to (i) the magnetic waveform unit for analysis up to 180 Hz, (ii) the spectrum analyser up to 4 kHz, (iii) the Wide Band Data unit, also up to 4 kHz, (iv) the EFW experiment for the fast event detector, and (v) it has also been requested by the Electron Drift Experiment (EDI) (cf.3.4.2.).

b) Magnetic wave form unit

The magnetic wave form unit is made of three sections (Fig 1.2/2.2.b):

one unit of digitalization
one unit of output interface
one unit of calibration

i) digitalization unit:

The three magnetic components Bx, By, Bz, from the search coil preamplifier are filtered in two bandwiths 0-10 Hz and 0-180 Hz.

The pass filters are 7th order low pass section. They are known with an accuracy of 1% in amplitude and 1 degree in absolute phase. The sampling frequency is equal to 2.5 times the 3db point frequency of the filters. So, the rejection of the aliasing components is at least 40 dB. The flters are designed in close collaboration with E-field experiment to improve the E/B correlations.

The filtered signals are applied, after the selection of the bandwith, to three sampling and hold devices synchronized by DWP, then digitalized and sent to the DWP experiment. The same synchronisation signal is sent to EFW.

The selection between the two filters is made by the DPU according to the telemetry rate. The filtered signals are simultaneously sampled in a large dynamic range (96 dB) with a very short sampling time of about 10 micro seconds in order to guarantee an error in relative phase less than one degree at 180 Hz between the three components.

The samples are successively applied to a 16 bit analog to digital converter, the digital values are transmitted to the DWP experiment through one parallel interface.

The advantage of the digitalization at 16 bit is in the simultaneous analysis of the natural waves of low level (few pT per Hz-1/2) with the large signal induced by the rotation of the spacecraft in the environmental DC field, called spin signal (up to 100 nT at 0.25 Hz). With such a dynamic, there is no trouble shoot to expect at the invertion of the DC magnetic field at the magnetopause.

ii) output interface:

The output interface unit is used to make a distribution of the analog magnetic signals - called Bx, By, Bz - to the other users of the Wave Consortium and to the EDI experiment, over the 4 kHz range of the search coils.

iii) calibration:

Two calibration sequences can be commanded by the DWP to calibrate in flight the STAFF experiment (the magnetic wave sensors and the wave form unit as well as the spectrum analyser).

The duration of each sequence is about 3 minutes.

Two types of signals are foreseen:

- sinusoidal at 7 Hz and 100 Hz.
- peudo random noise covering the 4 kHz bandwith of the spectrum analyser as well as the wave form filters.

Eigh amplitude levels will be available for each calibration signal, covering a range of 80 dB.

The signal of calibration will be simultaneously sent to the ground by telemetry through one channel (Bz) of the magnetic digitalization without filtering. It is called the REF signal. For doing so, the complete magnetic calibration is made in two steps. The REF is used as a reference channel for the phase measurements.

The sequences of calibration are commanded step by step by the DWP. For safety reason, the ON/OFF calibration is electrically redondant on the OFF order.

c) The spectrum analyser

The spectrum analyser is designed to perform the complete auto- and cross correlation matrix of 5 sensor channels over a frequency range of more than 9 octaves at a high rate.

The "front-end" of the analyser is analog. It consists of 15 variable-gain amplifiers and 15 anti-aliasing filters. The analysis band of 8 - 4000 Hz is divided into 3 logarithmically distributed frequency sub-bands, each with the maximum frequency 8 times the minimum frequency. For each of the 3 sub-bands and for each of the 5 sensor channels there is a separate controlled-gain amplifier (AGC) and separate band-pass filtering. The AGC amplifiers normalise the output signals to an optimum level for digitisation. For spin-plane sensors (Ey, Ez, By, Bz) the total power from the 2 sensors is used for the normalisation because the sensor outputs will have to be "de-spun" later (see below). The simplified block diagram of Figure 1.2/2.2.c shows the principle of the gain normalisation.

The dynamic range of the normalisation is 80 dB, which, combined with the 45-50 dB dynamic range of the digital processing, gives a total instrument dynamic range of the order of 120 dB. Separate high-pass and low-pass filters insure that the gain normalisation is only performed for signal components with frequencies within the sub-band which will be further analysed digitally, and more important, will prevent "aliasing", i.e. unwanted contribution from frequency components above the Nyquist frequency (sample frequency/2).

The 15 amplifier outputs are multiplexed together to a single 8-bit flash A/D converter. They are digitised in a rapid-fire mode by groups of 5 or 10, as needed at a 16 kHz rate. The 9 AGC gain-control signals are digitised separately to be included in the telemetry packets, as a multiplicative factor for the results of the subsequent digital filtering.

The digital processing of the sampled inputs is performed in 3 distinct steps: 1) de-spin of the spin-plane sensor outputs, 2) determination of the complex Fourier coefficients, and 3) calculation of the correlation matrices. This is described in the onboard software section below.

d) Operational modes

Eleven operational modes are presently foreseen (see Tables 1.2/2.2):

- a "normal" mode with auto-spectra taken every 1s, and the complete matrix every 4s (the wave form being transmitted up to 10 Hz in the normal (low) bit rate);

- 3 "fast" modes with auto-spectra every 0.125 s or every 0.250 s and the complete matrix every 1s, and the wave form up to 180 Hz. These modes are to be used when the high speed tape recorder is made available;
- a special "low power" degraded mode; in that case, 3 of the 5 wave components are selected and only 9 elements of the spectral matrix are computed (instead of 25);

- 2 degraded modes: wave form only (10 or 180 Hz). Those are very degraded modes which should be used in very limited occasions;

- 2 calibration modes: one in the normal bit rate and the other in the "burst mode".

Tab 1.2/2.2 operational modes

NORMAL MODE							secondary power= 1.75 W			
band	auto			cross			AGC			
	res		b/s	res		b/s	res		b/s	
A 8- 64 Hz	1.	s	360	4.	s	180	1.	s	24	
B 64- 512 Hz	1.	s	360	4.	s	180	1.	s	24	
C 512-4096 Hz	1.	s	360	4.	s	180	1.	s	24	
			1080			540			72	

LOW POWER MODE							secondary power= 1.45 W		
band	auto			cross			AGC		
	res		b/s	res		b/s	res		b/s
A 8- 64 Hz	1.	s	216	1.	s	216	1.	s	16
B 64- 512 Hz	0.5	s	432	1.	s	216	0.5	s	32
C 512-4096 Hz	0.5	s	432	1.	s	216	0.5	s	32
			1080			648			80

FAST/1 MODE							secondary power= 1.50 W	
band	auto		cross			AGC		
	res	b/s	res		b/s	res	b/s	
B 64- 512 Hz	0.125s	2880	1.	s	720	0.125s	192	
C 512-4096 Hz	0.125s	2880	1.	s	720	0.125s	192	
		5760			1440		384	

FAST/2 MODE							secondary power= 1.50 W	
band	auto		cross			AGC		
	res	b/s	res		b/s	res	b/s	
B 64- 512 Hz	0.250s	1440	1.	s	720	0.250s	96	
C 512-4096 Hz	0.250s	1440	1.	s	720	0.250s	96	
		2880			1440		192	

FAST/3 MODE secondary power= 1.50 W						
band	auto res	auto b/s	cross res	cross b/s	AGC res	AGC b/s
B 64- 512 Hz	0.125s	1728	1. s	270	0.125s	128
C 512-4096 Hz	0.125s	1728	1. s	270	0.125s	128
		3456		540		256

With the telemetry needed for wave-form data, the total resource requested by STAFF is :

3 kbit/s in normal mode
24.2 or 21.2 kbit/s in high rate mode

e) Onboard Software :

i) The Magnetic Wave Form

Due to the telemetry limitation, a reduction of the dynamic data range from 16 to 12 bits is performed inside DWP.

ii) The STAFF spectrum analyser

The digital processing of the sampled inputs is performed in 3 distinct steps: 1) de-spin of the spin-plane sensor outputs, 2) determination of the complex Fourier coefficients, and 3) calculation of the correlation matrices.

The de-spinning operation involves processing of the two signals received by a pair of spinning dipole or search coils to make them appear as signals received by non-rotating sensors. This transformation is necessary because the spin period is generally not long compared to the measurement times. Each time samples are taken of the spinning sensor outputs; they will undergo the following calculations:

$$Va = Vy*Cos(m) + Vz*Sin(m), \quad Vb = Vz*Cos(m) - Vy*Sin(m)$$

where Vy and Vz are the spinning outputs, m the instantaneous angular position of the Vy sensor, and Va and Vb the expected outputs for non-spinning antennas at $m=0^{o}$ and $m=90^{o}$. It is foreseen that the reference for m will be the sun pulse supplied by the OBDH and that m will be derived from spacecraft-supplied spin rate signals.

The determination of the Fourier coefficients is performed using appropriate algorithms which are extensions of the Remez exchange algorithm. Each of the 3 sub-bands are divided into 9 logarithmically- spaced channels. The relative (3 dB) bandwidth of each is 26 %.

The required analysis times are variable, depending on the frequency sub-bands, ranging from 0.016 to 1.0 s.

The auto and cross-spectra are calculated by complex multiplication of the Fourier coefficients and accumulation of the products. The analyser stores all of the results during one measurement cycle of 4 s (in normal operating mode). 540 auto-spectral coefficients are stored. This corresponds to 5 real sensor amplitudes per frequency, 27 frequencies, and 4 sub-cycles of 1s each. The number of stored cross-spectral coefficients is 540, i.e., 20 off-diagonal matrix elements and 27 frequencies. Only one set of cross-correlation components are transmitted each 4 s in the normal mode.

All of these numbers are stored in the analyser as 40-bit numbers, representing power. Out of these 40 bits 24 are significant in the final results of the auto-spectrum calculations. They represent a dynamic range of 10*log10(2**24)=72dB. For better use of the telemetry bit rate allotment and to simplify interfaces with the DWP, the 24 bit amplitudes are log-compressed by software in the wave analyser before transfer to the DWP. The result of this compression for an amplitude Nin is

Nin = 2**(E-3) * (8+M)

where 5 bits are used to represent the exponent E and 3 bits for the mantissa M. The total possible dynamic range for this data presentation is 96 dB, while the average relative amplitude resolution is 0.38 dB.

The cross-spectral coefficients are sent to the DWP with the same compression technique. But only 4 bits will be put into the telemetry bit stream.

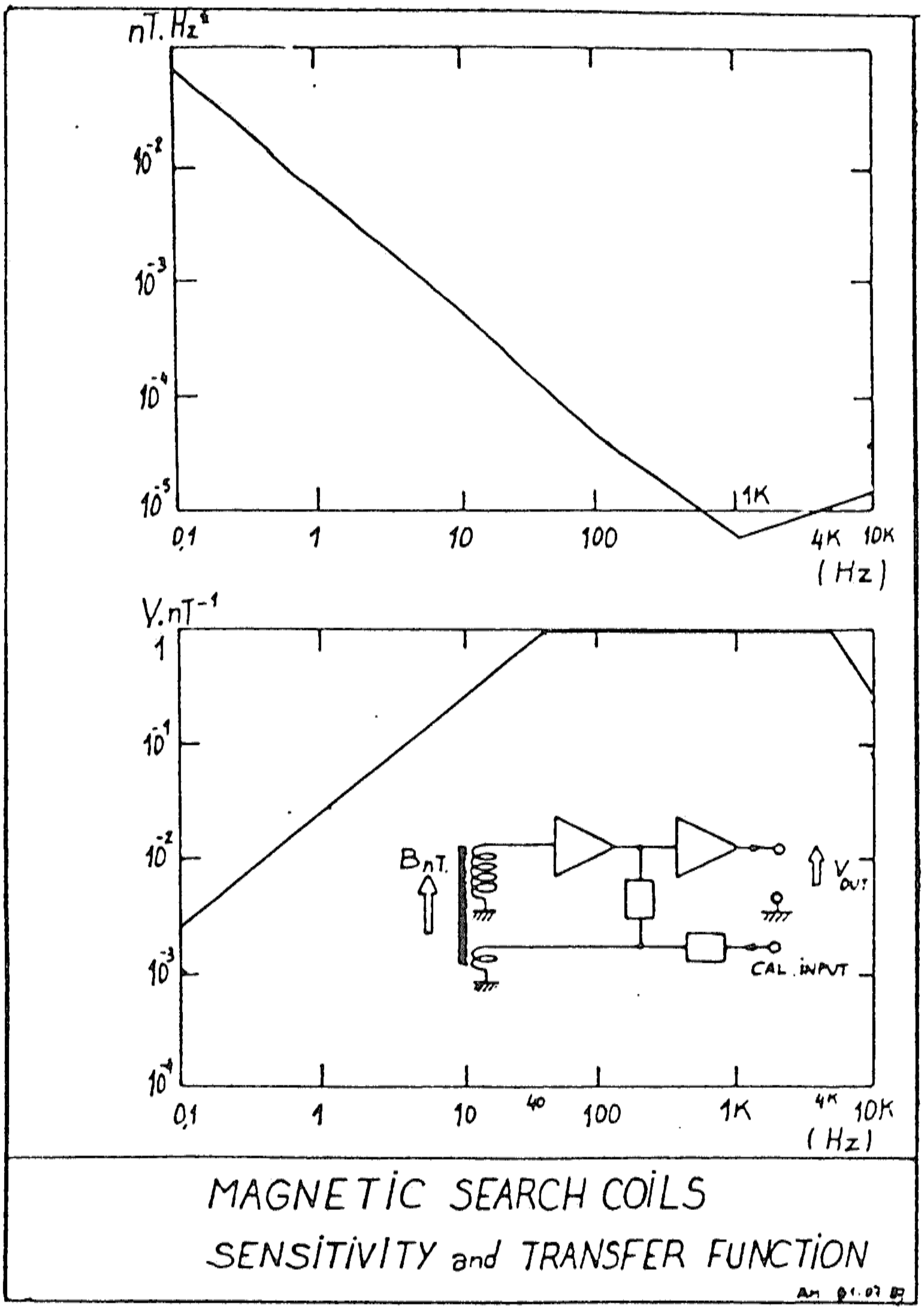
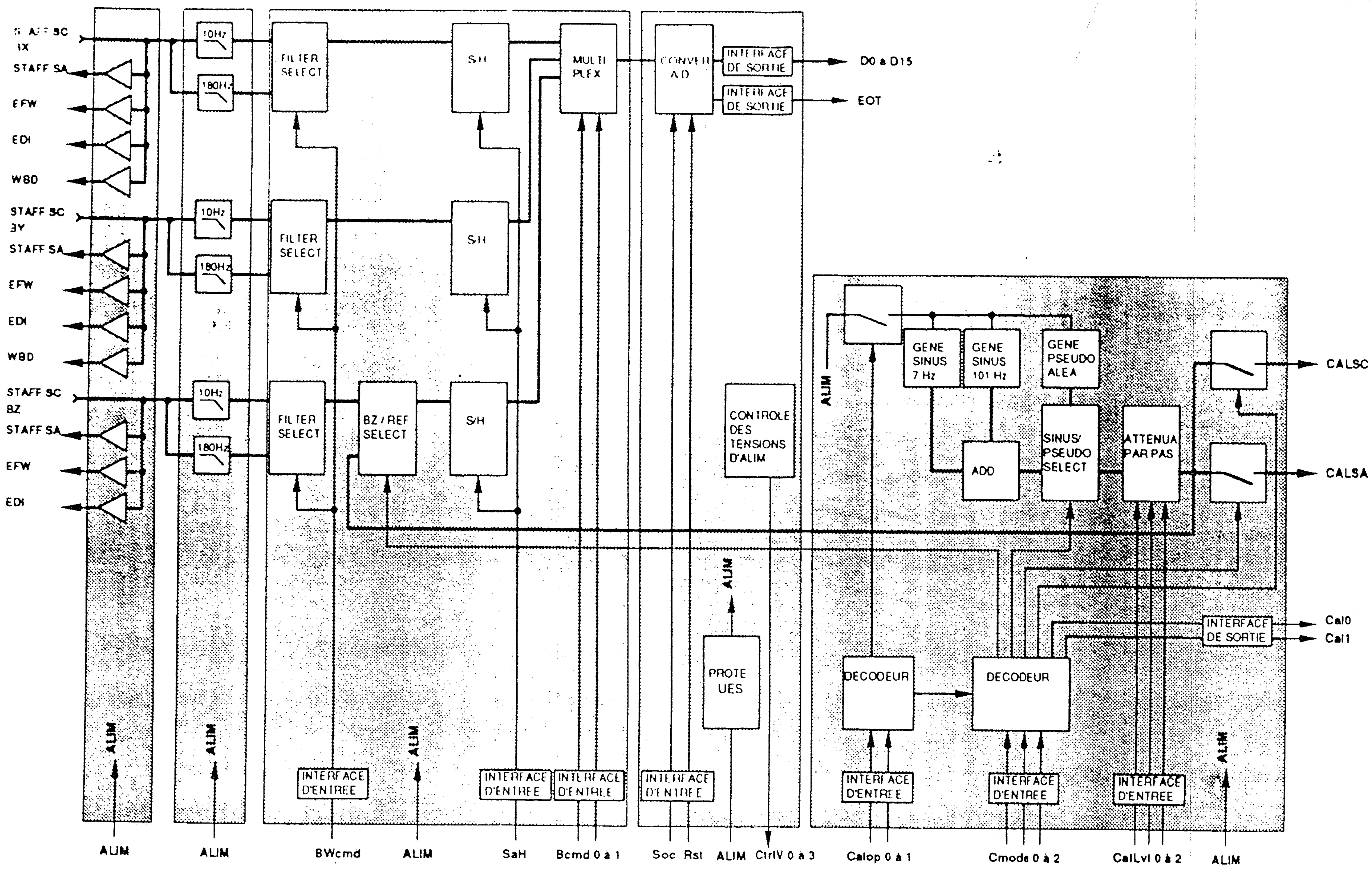


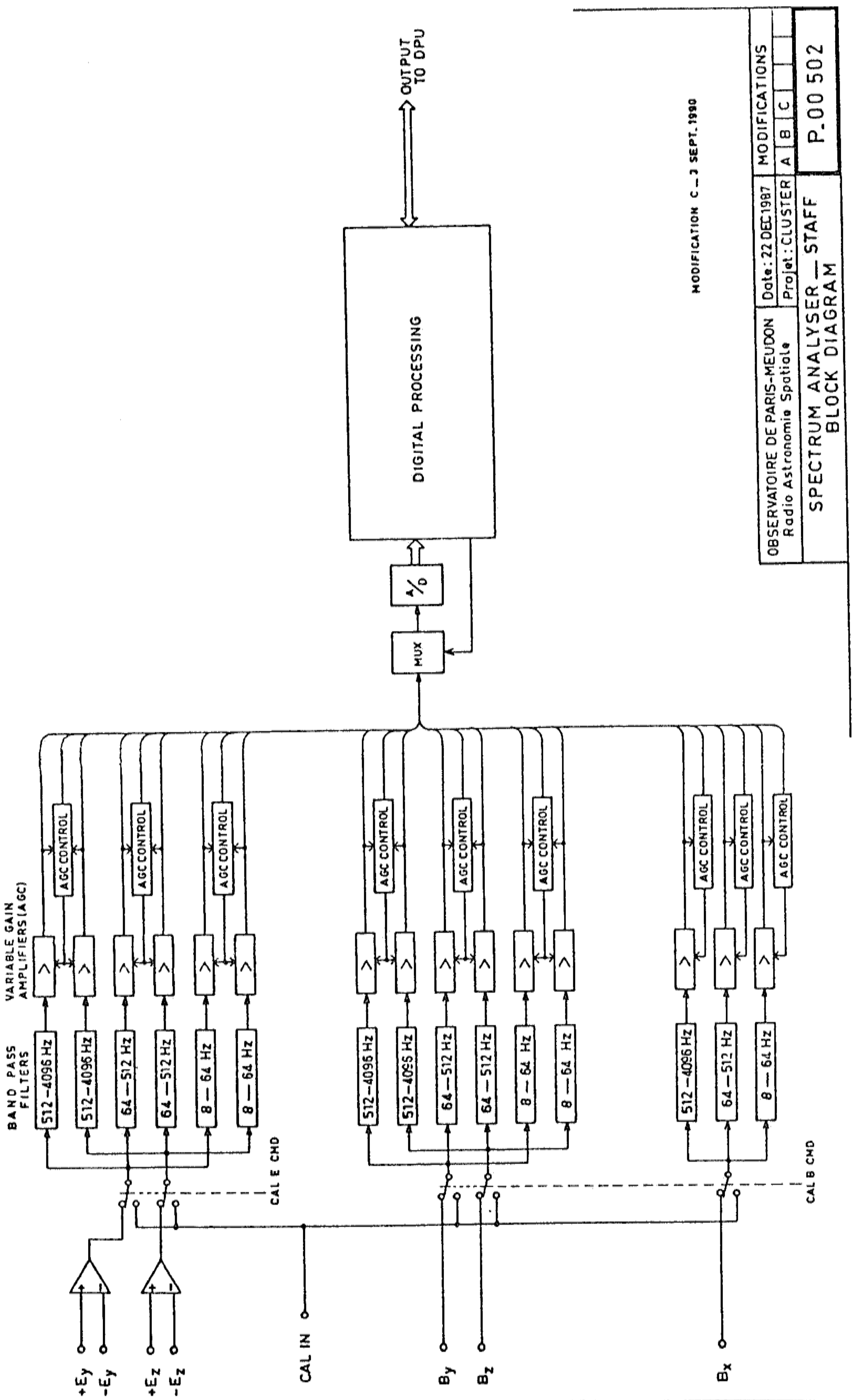
Fig: 1.2/2.2.a Main characteristics of STAFF receiver

Fig: 1.2/2.2.b block diagram of STAFF / Magnetic Waveforms



CLUSTER WEC 8 SYNOPTIQUE	VERSION: 2 DU: 19 SEPT.1990
CNET/CRPE 38,40 r du Gal. LECLERC 92131 ISSY les MOULINEAUX	PC CL SC0 W8

Fig: 1.2/2.2.c block diagram of STAFF / Spectrum Analyzer



1.2.2.3 WHISPER Brief Experiment Description

This instrument is basically a relaxation sounder which can also operate in passive mode. The WHISPER module includes a transmitter, a receiver, an analyser and interfaces circuits. WHISPER is controlled by the DWP (Digital Wave Processor) which is also part of the Wave Experiment Consortium Unit.

The transmitter is connected to the shield of one electric wire boom pair, Ey, (WEC 3 and WEC 4) through the electric field experiment module (WEC 5). A pulse of sine waves is transmitted during 1 or 0.5 ms at a frequency set by the DWP in the range from 4 kHz to 80 kHz. Different levels can be selected e.g. : 50, 100, 200 volts peak to peak.

The receiver is connected to the double sphere dipole probe Ez, (WEC 1 and WEC 2) corresponding to the other wire boom pair, through the electric field module (WEC 5), and is operated after the transmission of the pulse (the receiver is inhibited during the pulse). The signal received is amplified and analysed in frequency. In the baseline design, the analyser performs a FFT of 512 bins at most through a Digital Signal Processor (DSP) in the range 2-80kHz.

The output data from the analyser are checked, selected and compressed by the DWP according to the available telemetry. The receiver inhibit (blanking pulse or a digital word) is available to other instruments allowing sensitive circuits to be inhibited during the pulse transmission, which is of short duration relative to the receiving period.

The operational performance of the instrument corresponds to the following characteristics:

- Plasma densities from 0.2 to 80 cm^{-3} are measured with an accuracy of order 1% and a time resolution of, at best 1s.

- Natural wave electric fields are measured between 2 and 80 kHz, with a sensitivity of 1.4 $nV.m^{-1}.Hz^{-1/2}$ (TBC) and the product of time and frequency resolution equal to about 640 in routine, f.i. 1s and 640Hz, assuming a TM of 1200 bit s^{-1}.

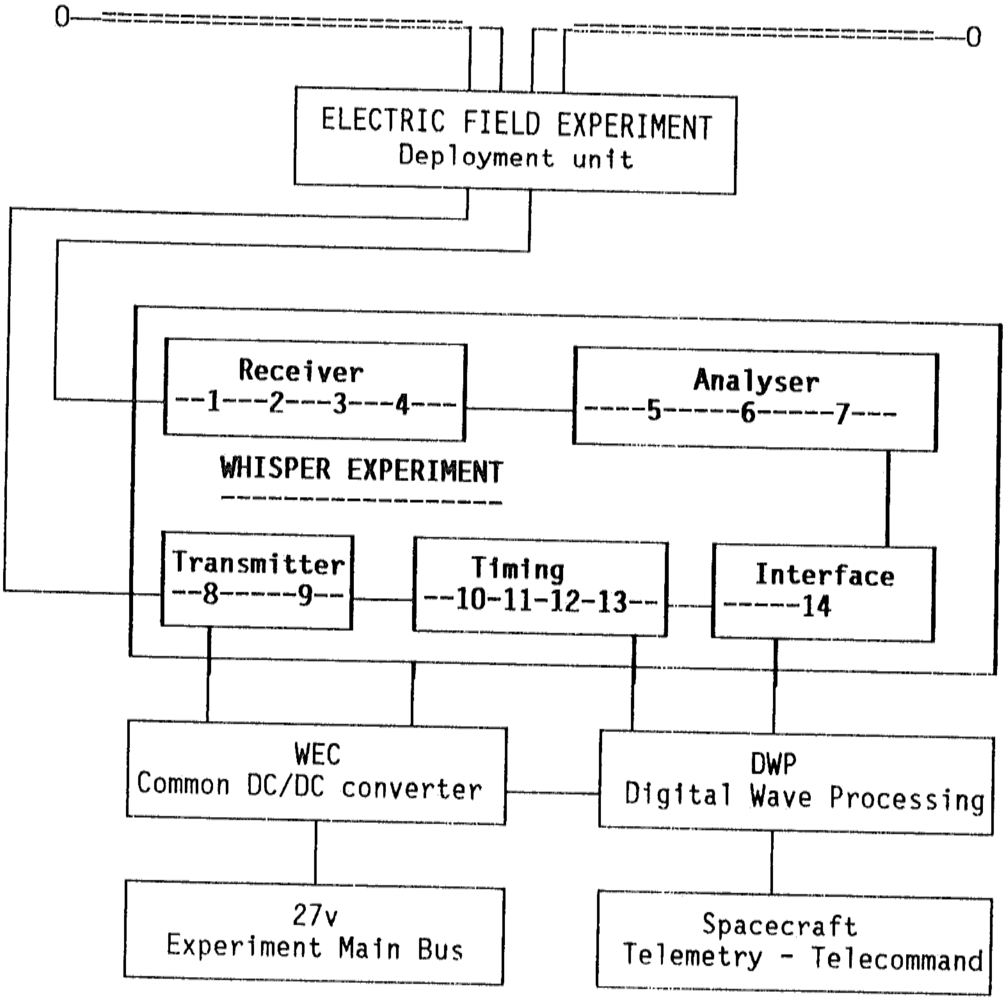
- The high stability of on-board frequencies leads to a negligible uncertainty on the frequency determination. The stability of the gain of the amplifiers, and the precision of their determination derived from ground and on-board calibrations guarantees a precision of about 5% in signal amplitude measurements. The matching of the transfer function between the four S/C will be performed with the same precision.

- The total dynamic range of the signal is of about 114dB (input signal from 2 µV to 1 Vrms). The dynamic range of the processing chain is 90 dB for a given operational mode. Each frequency line of the spectrum is expressed in a 16 bit word, which takes into account a variable gain (0 or 12dB) automatically adjusted in front of the chain. The position of the 90 dB dynamic range in the total 114 dB range considered for the input signal may be chosen by telecommanding the gain (0,12 or 24dB) of a second front amplifier.

Sensor associated Electronics Schematic.

The sensors associated to the WHISPER experiment are designed and built by the electric field experiment and are connected to the WHISPER module through the electric field module.

Fig 1.2/2.3.a Functional block diagram For WHISPER.



1 - Differential amplifier
2 - SGA (Stepped Gain Amplifier)
3 - Low pass filter
4 - A/D (Analog to Digital Conv.)
5 - Dual port memory input buffer
6 - DSP (Digital Signal Proc.) FFT
7 - Dual port memory output buffer
8 - Output power amplifier
9 - Signal syntethizer
10 - Micro-Controller
11 - PROM General program memory bank
12 - RAM Micro-Controller program memory
13 - RAM DSP program memory
14 - Data output parallel interface

Operational modes.

SOUNDING MODES (density and wave measurement)

Different modes are used by the WHISPER experiment, according to the scientific objectives aimed for, the available telemetry rate, and to the regions under study. It will be flexible enough to allow correlative on-board studies. In these modes, the total frequency range, n kHz, will be covered in n steps of 1kHz or n/2 steps of 2kHz, in a special mode.

Each step has the basic configuration illustrated below.

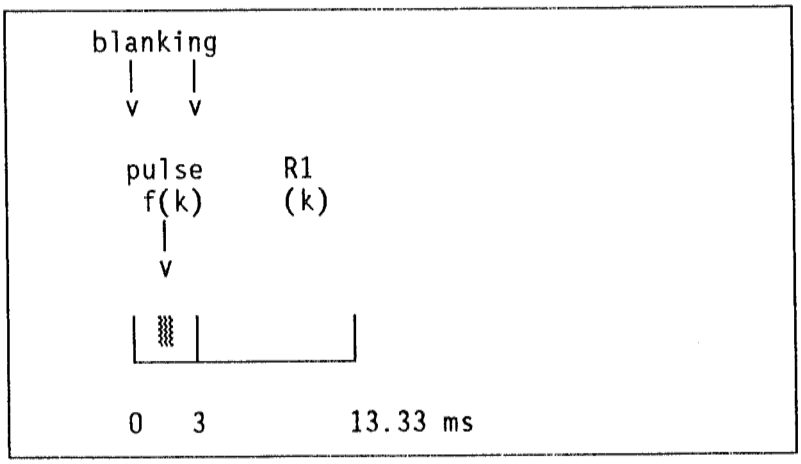


Fig 1.2/2.3.b signal duration

A sinusoidal wave, of frequency f(k) is transmitted during a pulse of 1 or 0.5 ms, inside a blanking period of 3 ms. The receiver is then activated during a receiving period, R1, of 10.33 ms. The step duration indicated in Fig.1.2/2.3.a, 13.33 ms, is a minimum value. The receiving period R1 can be followed by other receiving periods, R2, R3, etc. each of 13.33 ms, which leads to possible step durations of 26.66 ms, 39.99 ms and so on. The total sweep duration, T_s, is n times the step duration, T_p.

The natural noise is analysed via the DSP in parallel to the relaxation signals : out of the 512 bins obtained by FFT from the R1 sample, only 6 correspond to the 1 kHz frequency slice excited by the transmitter. Some bins correspond to a part of the frequency range which has been excited recently by the sounder. They show eventual responses damped according to their decay factor. Most bins correspond to a frequency range not excited recently, i.e. within the last 200 ms; they represent the natural noise. Several passive spectra are available after one sweep, by combination of all the bins with natural noise information.

NATURAL WAVE MODES (natural noise measurements)

When the density is not needed at a high rate, and for dedicated studies, we will use natural wave modes. The steps will be constructed only with receiving periods of 13.33 ms. For the base line design a complete spectrum of 512 bins is available after each receiving period. When the upper frequency is 80 kHz this leads to the best achievable resolution of 160 Hz in frequency, 13.33 ms in time.

CALIBRATION MODES

These modes will be run from time to time and set by command under control of the DWP to insure that the instrument is properly operating. The first one is achieved by connecting internally the output of the transmitter to the input of the receiver through an adequate attenuator and by checking the transfer function of the electronic circuits, this is the active calibration mode. During the active calibration, the instrument is connected to the antennae. The second one is achieved by connecting internally the output of the signal syntheziser to the input of the receiver through an adequate attenuator and by checking the transfer function of the electronic circuits, this is the passive calibration mode. During the passive calibration, the instrument is not connected to the antennae.

ON-BOARD SOFTWARE FUNCTIONAL DESCRIPTION.

Two different softwares will be run in the WHISPER experiment. One of them is used by the DSP for performing the various FFTs. The other one is used by the micro-controller which ensures the complete control of operations. Its main functions are to :

- Set-up the experiment according to the WHISPER command mode word sent by the DWP (see chapter 10.2 Modes of Operations).

- Load the needed FFT program into the DSP internal RAM.

- Generate and control the transmitted wave, in sounding mode, trigged by the DWP wich generate the synchronized "Blanking pulse".

- Dump the output data to the DWP.

- Run a "watch-dog" program against the radiation effect.

The WHISPER software package consists of a set of programs located in a common ROM, these programs are loaded in both the DSP RAM and the micro-controller RAM according to the current mode.

In addition the DWP contains software to control WHISPER and handle the DSP output. To control the instrument, the relevant Memory-load Commands must be decoded and messages sent to run WHISPER in the various modes (one message every 13.33ms, max). The data handling consists of treating the active output for a resonance recognition - in practice a selection of the n most significant peaks in a sweep - and compressing the passive spectra.

TELEMETRY MODES

The DWP software designed for the treatment of the frequency spectra delivered by the WHISPER module may be used with a very large flexibility. Each resonance recognised in a sounding mode is characterized by 23 bit (position, amplitude, decay). Only a few of them are transmitted in routine. The other part of the spectrum is divided in several frequency slices of equal width (then characterized by their averaged amplitude), or of equal averaged amplitude (then characterized by their width).

In natural wave modes, the characteristics of the spectrum (which represent several spectra averaged in time) are also organised in frequency slices. More sophisticated treatments (data compaction) are also foreseen. The resulting information consists in a maximum of 512 words of 8 bit per spectrum. It is compressed by average over time and/or frequency, with the value of the product delta f delta t (df*dt) of the frequency and time resolutions adjusted to the available telemetry rate.

Three TM rates are presently foreseen, used as shown in the following table.

WHISPER Telemetry rate						
TM mode	WHISPER mode	Resonances line/s	Resonances b/s	Spectrum df*dt	Spectrum b/s	Total rate * b/s
Routine 1200 b/s	S (1)	15	345	act 2600 pas 1280	256 512	1200
	N (2)	----------		640	1024	1100
High rate mode 1 8000 b/s	S (1)	128	2950	act 1280 pas 160	512 4096	7900
	N (2)	----------		80	8192	8250
High rate mode 2 17000 b/s	S (1)	512	7200	act --------- pas 160	 4096	11350
	N (2)	----------		40	16400	16500

(1) Sounding mode df ≥ 1 s
(2) Natural wave mode df ≥ 160Hz dt ≥ 13.33 ms
* Including mode status : TCMD word, Overflows, scale factor ....

The figures indicated in the table are obtained as follows :

a) in a natural wave mode, a full spectrum (512 frequency points, R.f min = 160 Hz) is covered in 4096 bit, as we use 8 bit words (each spectrum is associated with a scale factor, contained in the mode status information, which is adjusted to the maximal amplitude observed in the spectrum). The available TM rate, r, expressed in bit/s is used as follows :

$$r = (4096 / dt) \times (df\ min / df)$$

Any combination of df and dt which maintains the fixed value :

$$df*dt = \frac{4096 \times df\ min}{r}$$

can be used.

For example, we foresee a mode in routine :

(r = 1024 bit/s) where dt = 1 s, df = 640 Hz.

In the high rate mode 2, with r = 16400 bit/s we can reach dt = 62.5 ms with df = 640 Hz.

b) in a sounding mode, two types of frequency spectra are obtained :

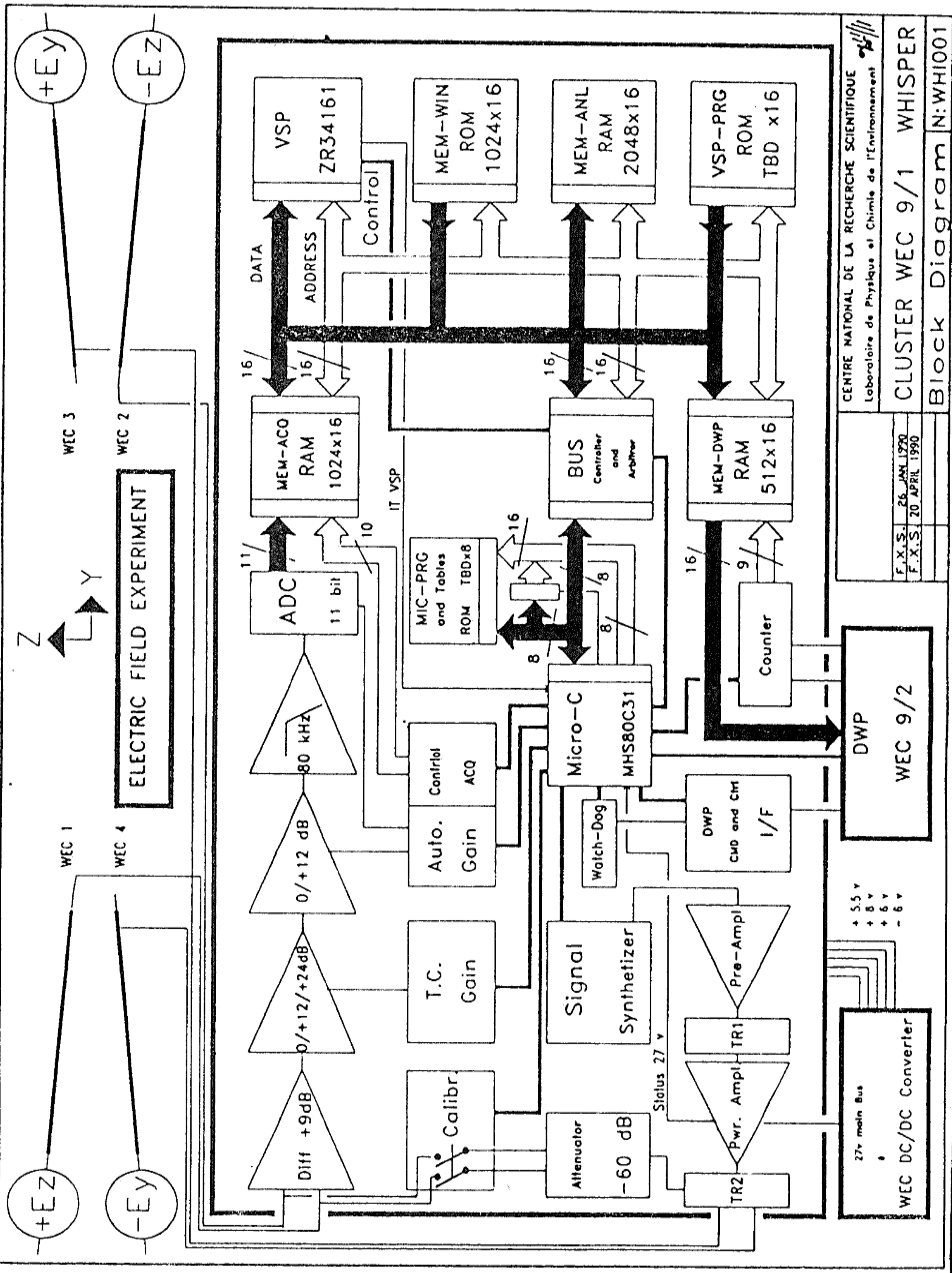
- the active one (the immediate response of the plasma to the excited frequencies)

- the passive one (the natural background emissions).

Those informations are covered as explained above, with R.fR.t values which are function of the TM rate we choose to allocate to each spectrum.

In addition, we transmit the full information (23 bit/line) concerning a given number of resonances. In case each of the 512 lines is described (as in high rate mode 2), only 14 bit/line are necessary, as their positions are known.

Fig: 1.2/2.3.c WHISPER block diagram



1.2.2.4 **WBD Brief Experiment Description**

a) Scientific Objectives

The primary objective of the WBD investigation is to provide the high resolution spectral analysis required to clearly identify the types of plasma waves detected in various regions of the terrestrial magnetosphere. Using the high-rate (approximately 262 kbit/sec) data link, the wideband receiver system provides wideband waveform measurements of both electric and magnetic fields over the frequency range 10 Hz to approximately 600 kHz.

The high resolution wideband data is of particular importance for the proper identification and study of plasma emissions which have very complex frequency-time characteristics, such as the distinctive fine structures of whistler-mode chorus or the auroral kilometric radiation. At boundaries and other regions with steep spatial gradients, the wideband data provides high time resolution measurements for comparison with data from other instruments with good temporal resolution, such as the magnetometer and plasma instruments. In this way, waves produced by current-driven instabilities and other mechanisms involving spatial inhomogeneities can be clearly identified. In cases where the upper hybrid or electron plasma frequency can be identified, the wideband data also provides very high resolution passive measurements of the electron density.

As often as is feasible, two-point measurements of magnetospheric plasma emissions are to be obtained with the Cluster wideband system. Two-point comparisons of electron densities from the upper cutoff of auroral hiss, for example, can be used to analyse the motion and evolution of plasma structures in the auroral zone and polar cup.

b) Hardware Functional Description

The CLUSTER wideband receiver is based on almost identical systems flown on the ISEE-1 and -2 and DE-1 spacecraft. A simplified block diagram of the basic system is shown in Figure 1.2/2.4, and the corresponding instrument parameters are shown in Table 1.2/2.4. The wideband receiver processes signals from one of four sensors which can be chosen via an analog antenna selection switch located at the receiver input. The four selectable inputs consist of two electric field signals (Ey,Ez), and two magnetic field signals (Bx,By) provided by the electric and magnetic field experiments.

The output from the antenna selection switch goes to a single-sideband frequency converter which determines the frequency range to be received. The conversion frequency is obtained by dividing down from a 14 MHz reference oscillator. To maintain phase stability in the entire system, the 14 MHz oscillator is synchronised to a spacecraft high frequency (220 kHz) clock. One of four frequency conversion signals can be selected: f = 0 (baseband), 125 kHz, 250 kHz, and 500 kHz. A spacecraft command to select a particular frequency band causes the DWP to switch the wideband receiver to the appropriate input bandpass filter and to select the appropriate conversion frequency. If baseband is selected, the mixing stage is bypassed so that the signal is transmitted directly with no frequency conversion.

Table 1.2/2.4. Wideband Instrument Parameters

Sensors	Two electric antennas; two search coil magnetometers.
Conversion Frequencies:	0, 125 kHz, 250 kHz, 500 kHz
Bandpass Filter Ranges:	1 kHz to 77 kHz 50 Hz to 19 kHz 10 Hz to 9.5 kHz
Gain Select	5 dB steps, 16 levels, dynamic range 75 dB, automatic ranging or set by command
A/D Converter:	1 bit 219.5k samples/sec 4 bit 54.9k samples/sec 4 bit 219.5k samples/sec 8 bit 27.4k samples/sec 8 bit 54.9k samples/sec 8 bit 219.5k samples/sec

The output from the frequency converter then goes to a bank of three bandpass filters, one of which can be selected by command. The filter bandwidths are 10 Hz to 9.5 kHz, 50 Hz to 19 kHz, and 1 kHz to 77 kHz. The selected filter determines the bandwidth of the output waveform.

Because of the large dynamic range of the input signal, and in order to maintain a high signal-to-noise ratio for the processed signal, an incremental automatic gain control provides amplification to a selected level in steps of 5 dB over a range of 75 dB. The gain select can be operated in either an automatic or manual (command) mode. In the automatic mode, a commandable threshold is incorporated into the feedback loop to avoid excessive toggling between gain steps.

The output analog waveform is then sampled by an analog-to-digital converter which provides 1-bit, 4-bit, and 8-bit resolution at sample rates of 219.5k, 54.9k, and 27.4k samples/sec. The allowed resolution and sample rate combinations are listed in Table 1.2/2.4.

1.2.2.5 DWP Brief Experiment Description

The Digital Wave Processing Experiment, DWP, will be flown on the four ESA/NASA Cluster satellites as a component of the Wave Experiment Consortium (WEC). The wide variety of geophysical plasmas which will be investigated by the Cluster mission contain waves with a frequency range from d.c. to over 100 kHz with both magnetic and electric components. The characteristic duration of these waves extends from a few milliseconds to minutes and a dynamic range of over 90 dB is desired. All of these factors make it essential that the on-board control system for the WEC instruments is flexible so as to make effective use of the limited spacecraft resources of power and telemetry information bandwidth.

The processing system within the DWP instrument will also perform particle and wave-particle correlations so as to study directly wave-particle interactions.

The DWP instrument employs a novel architecture with parallel processing and re-allocatable tasks to provide a high reliability system.

Studies of small-scale plasma structures and boundaries are important objectives of the Cluster mission. These structures include Flux Transfer Events (FTE's), solar wind current sheets (SWCS's) and plasma sheets. The boundaries are such as the magnetopause and bow shock. One of the possibilities afforded by Cluster will be to test if these boundaries are in fact quasi-planar as is at present generally assumed. Plasma waves are important in the study of processes at such structures and boundaries. They are probably responsible for the anomalous resistivity in magnetic reconnection and the energy dissipation at shocks.

Wave measurements are also important as indicators for studying boundaries and small scale structures. Schwartz et al and LaBelle et al have shown that waves are observed at SWCS's and FTE's respectively. Farrugia et al have presented a multi-instrument study of FTE's in which wave measurements were important in the identification of different regions. Woolliscroft et al reviewed observations by AMPTE at small scale structures. The important conclusion is that wave experiments are high time resolution indicators of different plasma regimes. Plasma experiments (ion and electron spectrometers etc) typically take half or one spacecraft spin (of the order of a few seconds) to measure the plasma regime, ie. the particle distribution function, and magnetometer data alone are not sufficient to determine plasma conditions. High time resolution information, such as can be obtained from wave experiments, are important in a spatio-temporal study by multiple spacecraft. Data from the AMPTE UKS spacecraft at the edge of a SWCS show that plasma waves in the 0.11-3.9 kHz band cease in less than about 1 second at the edge of the event.

In order to fully utilise the capabilities of wave measurements to characterise small scale structures it is important that effective use is made of the limited telemetry bandwidth which is available.

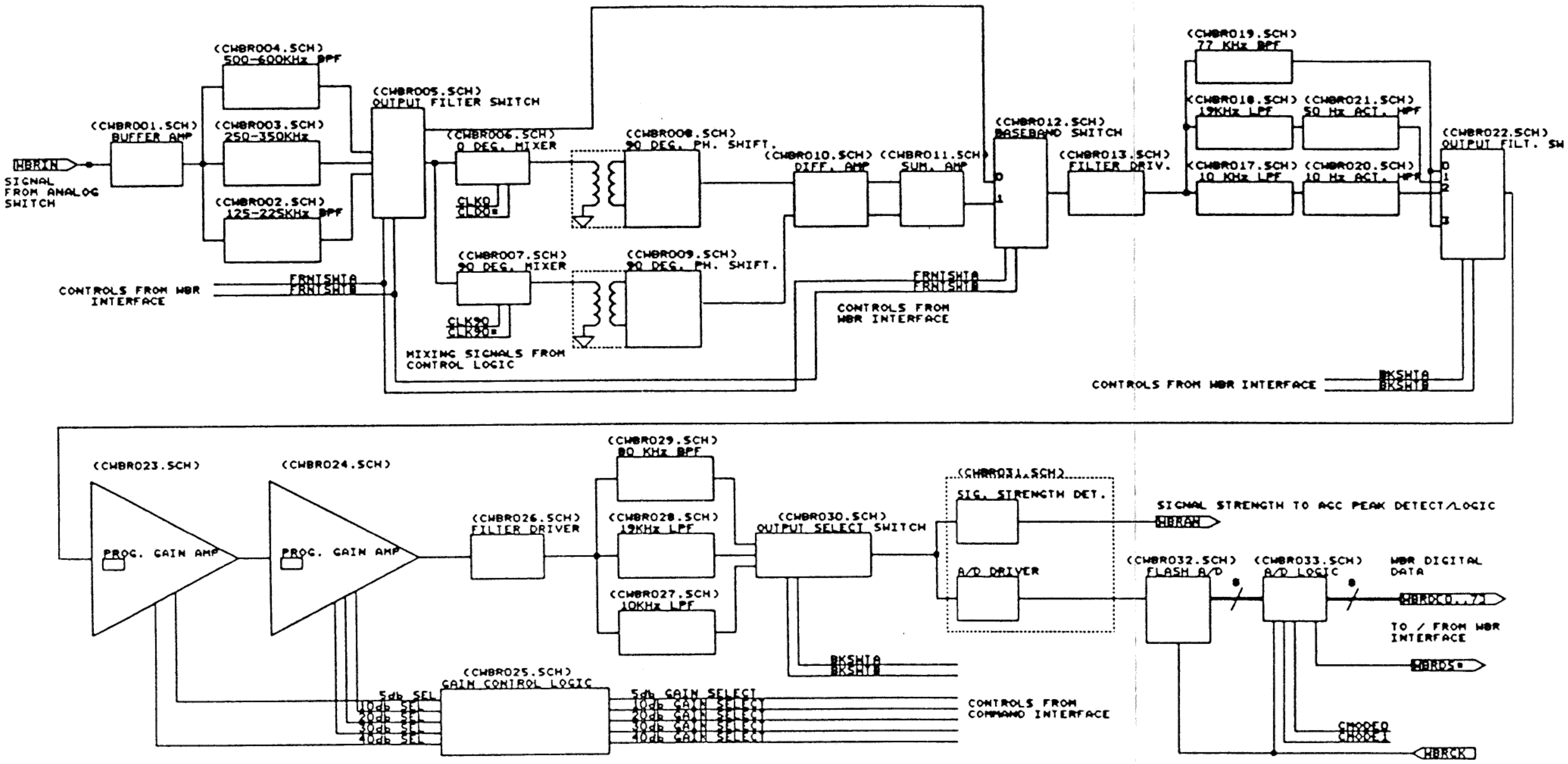
Particle and Wave-particle correlation is a novel diagnostic technique based on forming autocorrelation functions of the time series of particle detector counts as a function of energy and pitch angle, or in the wave-particle mode, computing the cross correlation of counts with signals from, for example, the electric field antenna. The basic P-WPC operations will be carried out in DWP resident software using algorithms developed for AMPTE, CRRES and rocket experiments and also from computer simulations. The particle correlator technique permits; a) the detection of particle flux bursts on timescales short compared to the energy dwell time, b) indication of regions of velocity space in which wave particle interactions are occurring and c) in its wave-particle mode, allows study of regions of velocity space associated with low frequency wave activity.

A problem common to most space instruments is due to restrictions on the available telemetry bandwidth. This can be particularly severe for wave experiments where the mismatch between information and telemetry bandwidths can be several orders of magnitude. In order to improve the use of available telemetry it is proposed to employ data compression techniques in the DWP instrument.

Data compression allows more useful information to be transmitted over a given telemetry system than would otherwise be possible. This is achieved by removing redundant information from the data. Various data compression methods are currently being investigated for Cluster. The results vary with the type and variability of the data, but compressions to between one half and one twentieth of the original number of data bits are being achieved with zero or negligible distortion of the data. Results on test data from the AMPTE UKS show very little degradation after compression to roughly one third of its original size.

A format generator then organises the digitised waveform into an output frame tagged with a time marker which relates to the spacecraft clock time (1 microsecond resolution) and makes the frame available to the spacecraft telemetry system. For sample rates where the bit rate exceeds the spacecraft telemetry data rate, the digitised wideband data is buffered by the format generator and read out at a reduced average bit rate.

The wideband receiver provides two different output modes for the transfer of digitised data to the spacecraft data system. These consist of a real-time data mode which provides data at about 220 kbit/s and a burst-data mode which provides data at about 73 kbit/s. In the 220 kbit/s real-time data mode, wideband digital data is read out directly to the spacecraft telemetry system and is transmitted by the spacecraft via a real-time link to a NASA DSN ground receiving station. The dedicated WBD burst mode provides high-rate data to the OBDH tape recorder via the WEC DWP. Data is transferred to the DWP through a serial interface at 220 kbits/s, and the DWP, in turn, reduces the WBD data by a factor of three (73 kbits/s) via digital filtering. The WBD data is then passed to the spacecraft data system for recording and subsequent playback. The dedicated WBD burst mode provides the capability for acquiring data when the spacecraft cannot be tracked by a DSN station, and also provides the means for collecting wideband data from more than one spacecraft at a time.



DRAWN	S. NANDA	DATE 05/22/90	UNIVERSITY OF IOWA DEPT OF PHYSICS & ASTRONOMY
DESIGNED	P. SHEYKO	02/06/89	Title: CLUSTER WIDEBAND RECEIVER (CWBR000.BLK)
PROJECT MGR			Size B Document Number 92-39000 REV A
			Date: July 6, 1990 Sheet of

Fig: 1.2/2.4 WBD block diagram

1.2.2.6 PWR (power supply)

In addition to the five experiments, the WEC power supply unit will be the single point interface with the spacecraft for the power distribution (excepted for the deployment motors). It contains all the ON/OFF switches and distributes within the WEC the main bus lines to EFW, WHISPER, WBD and regulated voltages to STAFF, WHISPER, DWP.

The specifications for the regulated voltages requested for "analog" and "digital" purpose are listed in the table below:

WEC POWER SUPPLY MAIN CHARACTERISTICS OF THE REGULATED VOLTAGES:

constraints	analog	logical	
regulation at ambient temperature (25°C)			
for 27.5 V +- 1 V at input	+- 1%	+- 3%	
for I nominal +- 50%	+- 2%		
for I = I nominal/10 to 2*I nominal		+- 5%	(**)
maximum noise level (voltage modulation)	10 mV(pp)	30 mV(pp)	(*)
stability in temperature			
operating range (-10 +45)°C	+- 1%	+- 1%	
non operating range (-30 +80)°C	+- 3%	+- 3%	

REGULATED VOLTAGES TO BE PROVIDED: revision Dec 89

experiment	analog	logical	I nominal
DWP		+ 5.65 V	320 mA
WHISPER	+ 8 V		15 mA
	+ 6 V		20 mA
	- 6 V		20 mA
		+ 5.5 V	210 mA
STAFF/spa	+ 6 V		75 mA
	- 6 V		75 mA
		+ 5.25 V	180 mA
STAFF/mwf	+ 9 V		20 mA
	- 9 V		20 mA
	+ 5.75 V		50 mA
	- 5.75 V		40 mA

(*) residual modulation and commutation peaks considered separately
(**) for DWP, the current limitation must be above 3 x I nominal