PS/OP/Info 92-04
4.2.1992

AAC RF SYSTEMS

Copie des transparents
du cours donné aux techniciens d'opération AAC/LEAR
le 4.2.1992
par L. Søby

Distribution

Section OP/AAC/LEAR
AAS

AAC RF Systems

AC H=6 :

Debunching of Injected $\bar{p}$'s $\frac{\Delta p}{p}$ = 6% → 1,5%

F_{RF} = F_{REV} * 6 = 9.53683 MHz (FIXED)

V_{RF} : 500 Vp → 1,2 MVP 2 gap's

AC H = 1 :

a) Bunching of Precooled $\bar{p}$ on Central orbit before transfer to AA

b) Manipulations of Testbeams - Q (f), orbit (f)

F_{RF} = 1587.2 kHz ± 1.5 kHz
V_{RF} = 1 vp to 3.5 kvp (1 gap) } GFA's.

AA H = 1 :

0) Bucket to Bucket transfer Between AA/AC
a) Bunching of Precooled $\bar{p}$'s
b) Transfer To stack
c) Unstacking of $\bar{p}$'s
d) Testbeam manips.

AAC RF Systems

AA H = 1 (cont.):

F_{RF} = 1850 kHz ± 10 kHz
V_{RF} = 5 Vp to 14 kVp (2 gaps } GFA

AA H = 160:

~~Controled blow up of stack prior to SPS dumps.~~

Not USED For Lear transfers

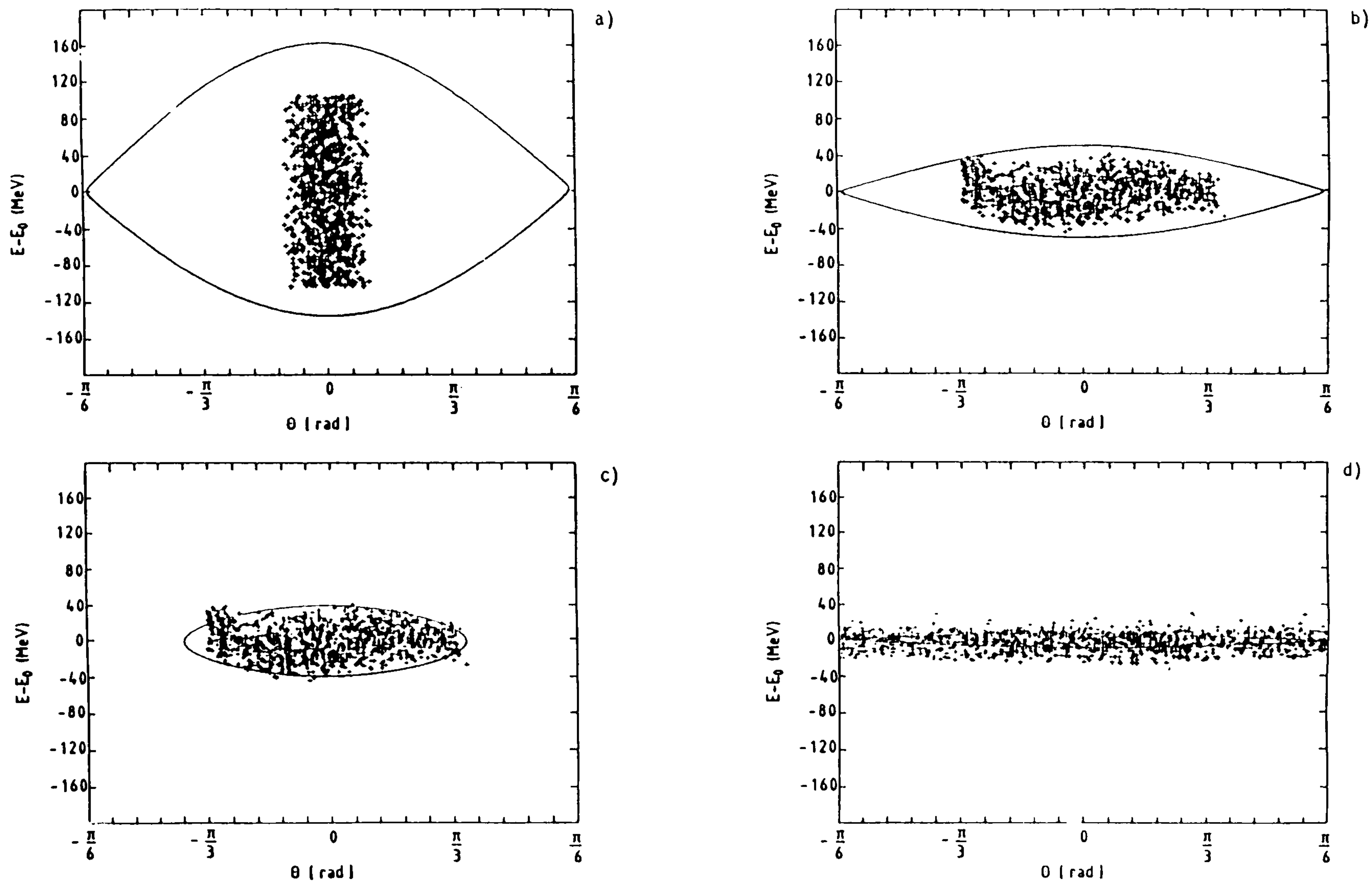


Fig. 13 Debunching in ACOL. (a) Initial configuration of the bunch in the longitudinal phase space. (b) After bunch rotation. (c) At the beginning of the adiabatic debunching. (d) After full debunching.

Table 3.2 summarizes the most important rf parameters. Figure 3.2 shows a practical voltage program.

Table 3.2

Voltage, rotation	1.32 MV_p
Bucket/bunch height	1.41
Harmonic number	6
Frequency	9.537 MHz
Rotation time	60.5 µs
Revolutions during rotation	96
Matching voltage (for initial bunch length of 25 ns)	297 kV_p
Debunching time	10 ms

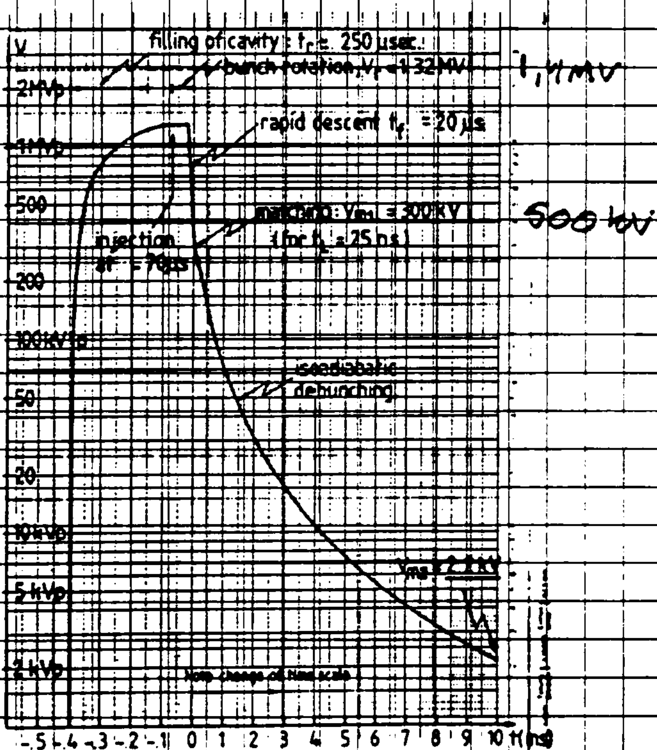


Fig. 3.2 Typical voltage program

3.3 Rebunching

To obtain a practically loss and dilution-free transfer of the pre-cooled beam from the AC to the smaller AA while providing reasonable gaps for the AC and AA kickers a rebunching rf system with harmonic number one is provided. This system also serves to manipulate proton test beams to explore the momentum aperture.

AC

n=6 FUNCTION NO. 4 1992-01-11-17:23:33

HOLD LEVEL	(kV/CAVITY)	700
MATCH LEVEL	(kV/CAVITY)	250
FINAL LEVEL	(kV/CAVITY)	3
DEBUNCHING TIME (ms)		20
ROTATION TIME (105 ns UNITS)		558
ADIABATICITY FACTOR		.15
DISCHARGE TIME (105 ns UNITS)		5000
FROM CX.IKIK-MSW		5000

THE ROTATION TIME AND ADIABATICITY FACTOR ARE CALCULATED ASSUMING THAT BOTH CAVITIES ARE WORKING WITH THESE PARAMETERS. IF ONLY ONE CAVITY IS USED, BOTH MUST BE MULTIPLIED BY 1.41.

[illegible] [illegible]

	CAV.1 2706	CAV.2 2506
LEVEL 1		
LEVEL 2		
DETUNED		
HOLD VOLTAGE,kV		
PHASE, degrees		
ON-OFF CONTROL		
VOLTAGE CONTROL		
PHASE CONTROL		
SYNTHESIZER		
ISO-AD.DEBUNCH.		
TIMING		
GAP VOLTAGE		
GAP PHASE		

	CAV.1 2706	CAV.2 2506
MAIN INTERLOCK		
AIRFLOW DRIVER		
AIRFLOW FINAL		
WATERFLOW DRIVER		
WATERFLOW FINAL		
FILAMENT DRIVER		
TEMP. FINAL		
FILAMENT FINAL		
WARM-UP FINAL		
SECURITY		
CATHODE SWITCH		
VACUUM		
-350V G1 DRIVER		
PREDRIVER		
+Ua DRIVER		
+Ua FINAL		
1.5kV DRIVER		
TUNING		

RFAC(2,COM1) 170 CAMAC ERROR (LOOK AT DETAILS BY PROP. CAMERR)

AC SELECT FILE

ACTIVE FILE SHOWN INVERTED

	LAST SAVED	LAST USED
1 STACKING 4.8 S	91-12-03	92-02-04
2 MODE 10 SPECIAL TRANSFER RF.	90-04-11	91-09-27
3 DEBUNCH P'S MODE 3	89-12-07	91-09-27
4 STACKING 4.8 S	90-09-12	91-09-27
5 DEBUNCH, CAPTURE, DEPOSIT	87-11-20	91-09-27
6 BLOW UP - COOL - REBUNCH FOR TRANSFER	87-10-07	87-11-18
7 CAPTURE DEB. P'S FOR XFER TO AA	88-03-28	92-02-04

AC **1 STACKING 4.8 S**

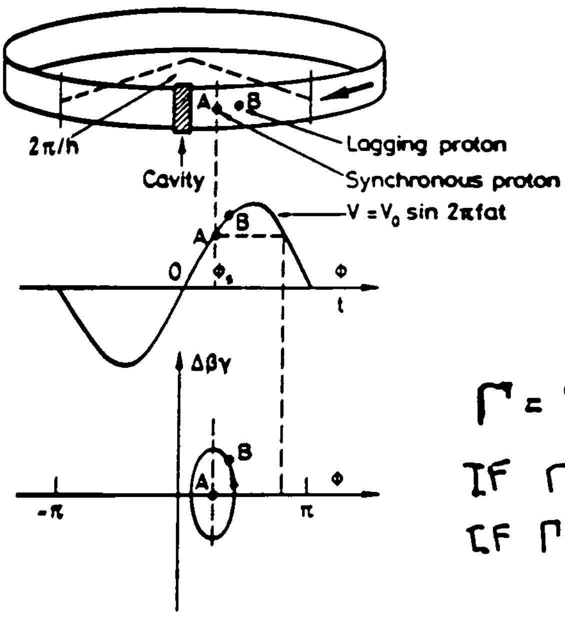
NO PHASE LOCK

SYNC DISABLED

SAVED 91-12-03 USED 92-02-04

			VALUES AT END OF SEQUENCE						
SEQ	TYPE	Δt	t-tini	f	A eVs	Γ	V	f_s Hz	VECT
1	INI	0	0	1588	.2978	0	2	2	1
2	[illegible]	.056	.056	1588	.2978	0	2	2	2
3	[illegible]	1.798	1.854	1588	.2978	0	2	2	14
4	[illegible]	2.39	4.244	1588	.2978	0	2	2	29
5	[illegible]	.02	4.264	1589.48	.3886	0	2	2	30
6	[illegible]	.5	4.764	1589.48	9.5	0	1195	50	40
7	[illegible]	.002	4.766	1589.48	9.4998	0	1195	50	41
8	[illegible]	.02	4.786	1588	.2978	0	2	2	42

max [illegible]



$\Gamma = \sin \varphi_s$

IF $\Gamma > 0 \Rightarrow$ Acceleration.

IF $\Gamma < 0 \Rightarrow$ Desacceleration

Fig. 22 Cylindrical coordinate system rotates with beam, demonstrates meaning of RF phase angle in longitudinal phase space

$$\beta = v/c$$

$$\gamma = E/E_0$$

$$P = (\gamma\beta)\,E_0$$

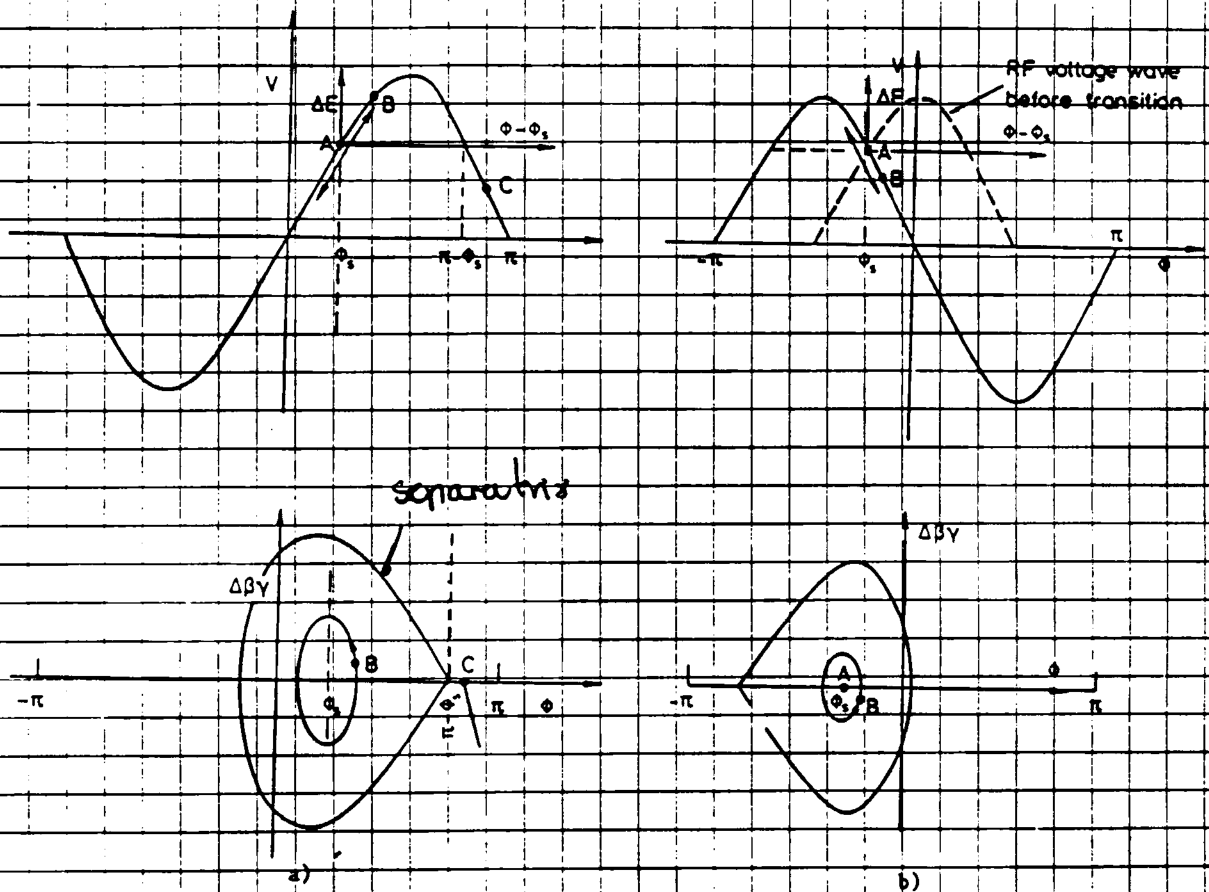


Fig. 23 Phase stability of synchrotron motion below (a) and above (b) transition

$$A_{Bs} = \frac{|E|}{h}\sqrt{\frac{h \cdot e\,V_{RF} \cdot E}{2\pi\,|\eta|}} \quad \text{eV.sec}$$

$$A_B = \alpha(\Gamma)\,A_{Bs}$$

Bucket area: $(heV)^{1/2}\,\alpha(\Gamma)\,(16\gamma/h)\,(2\pi E|\eta|)^{-1/2}$

Bucket (half) height: $(heV)^{1/2}\,Y(\gamma/h)\,(\pi E|\eta|)^{-1/2}$

Coordinates: $(\Delta p/m_0 c) - \phi$

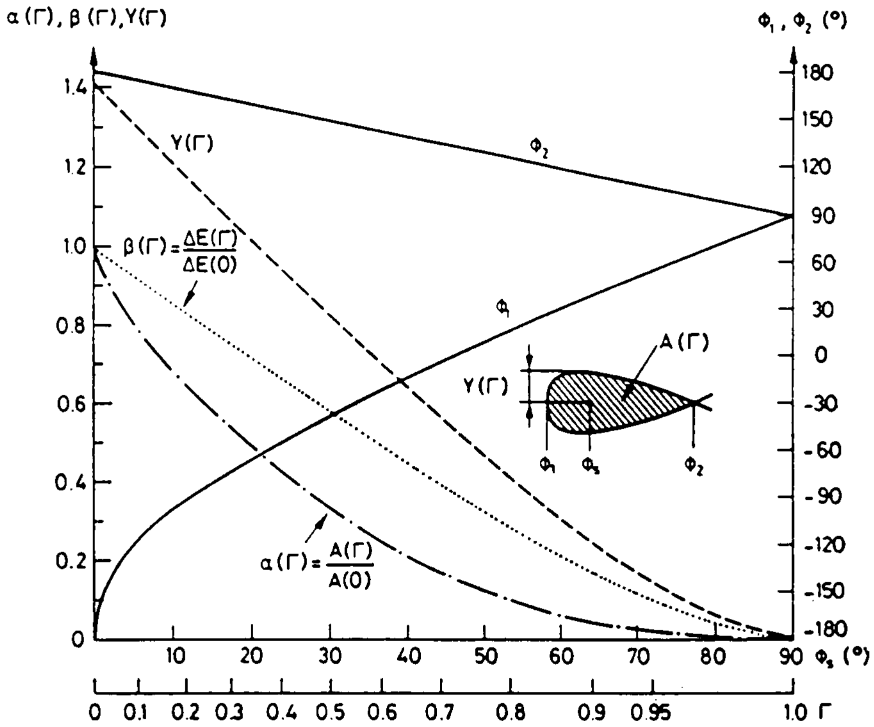
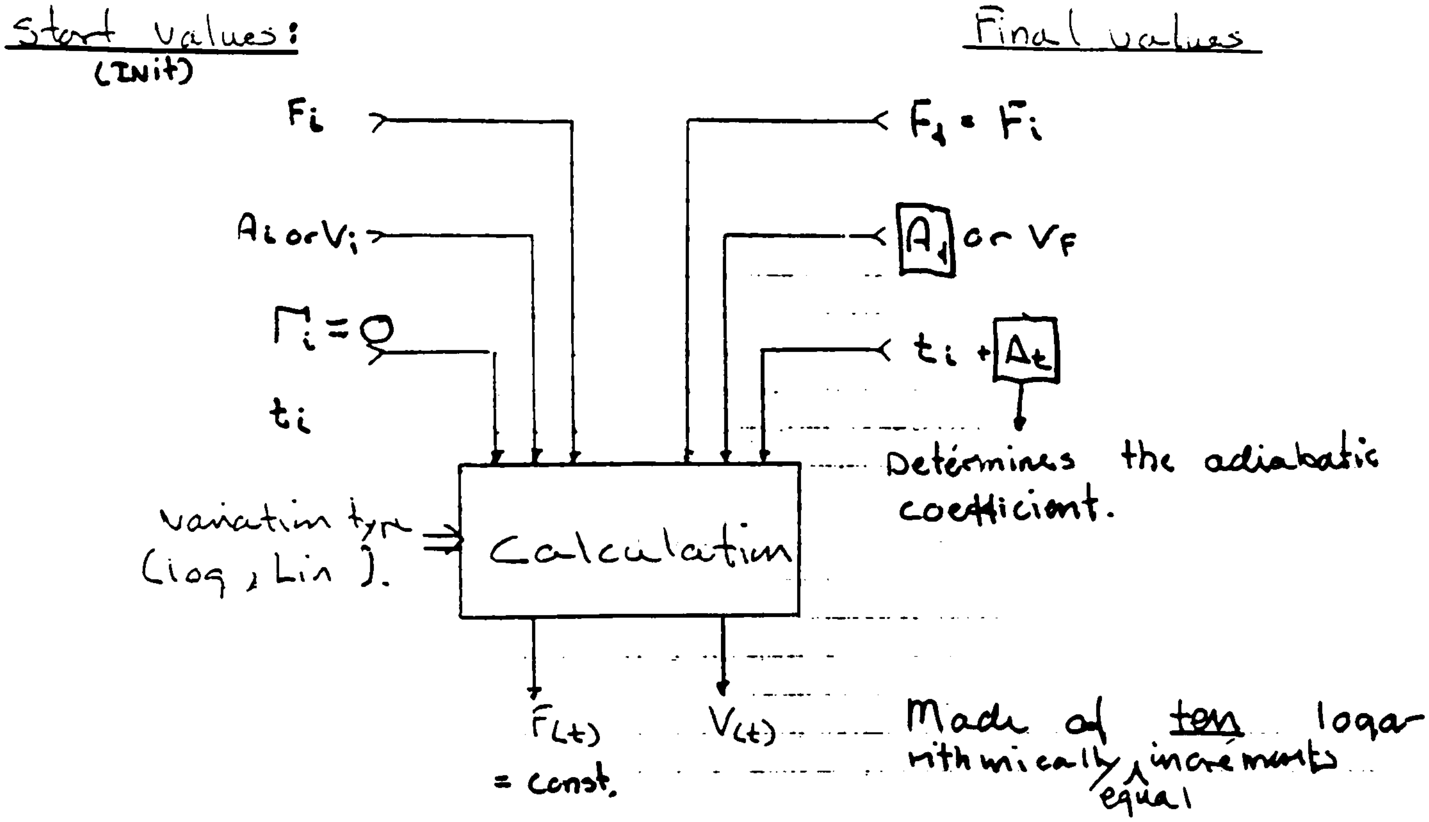
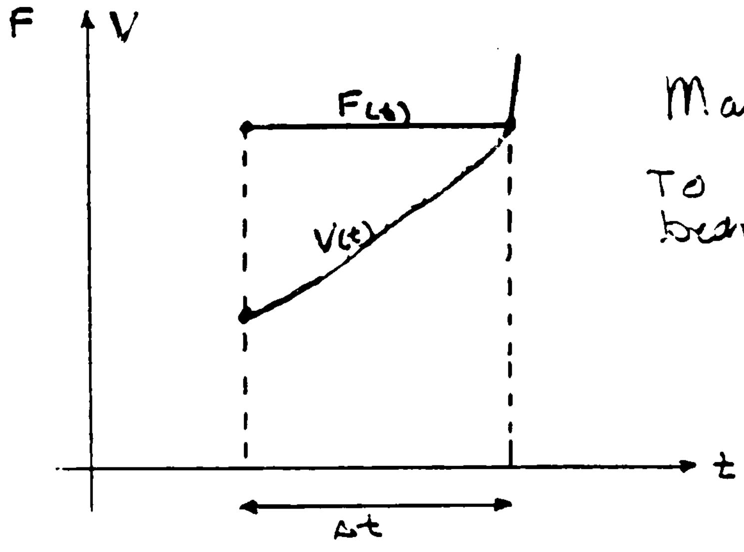


Fig. 27 Normalized bucket area and height (from Ref. 3)



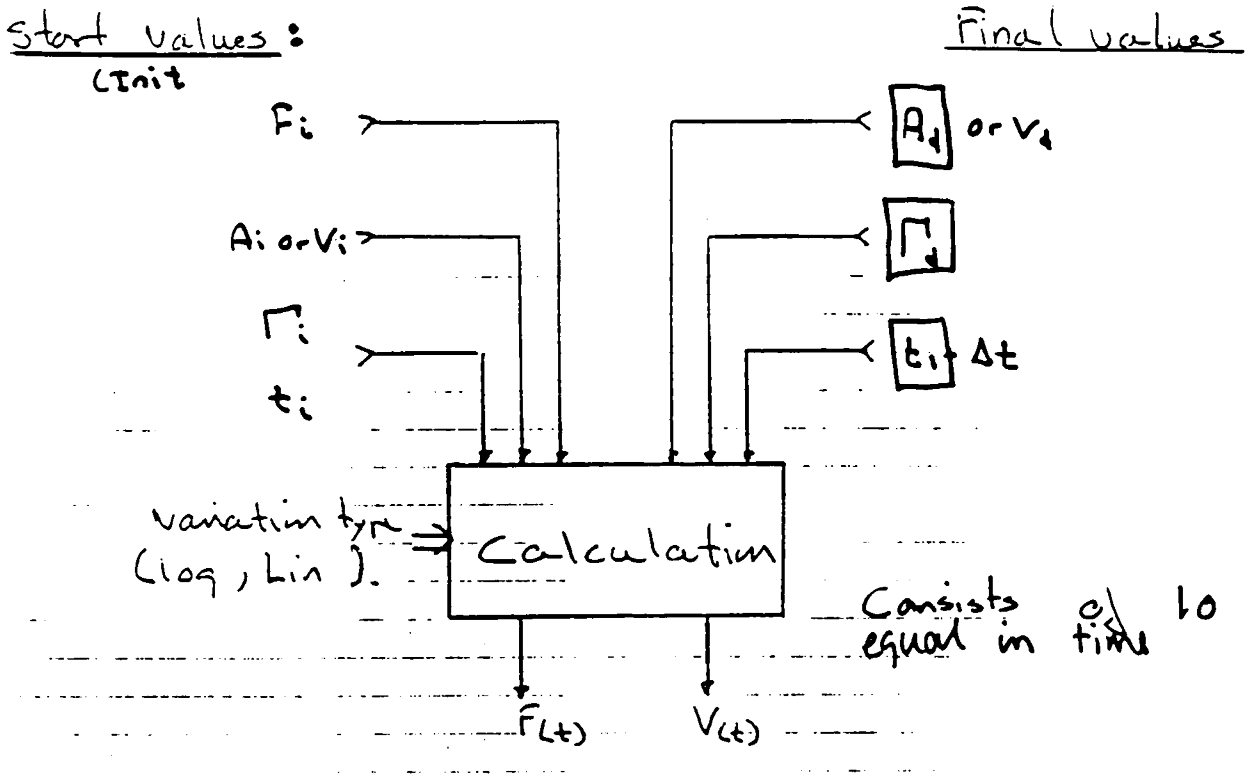


Main purpose:

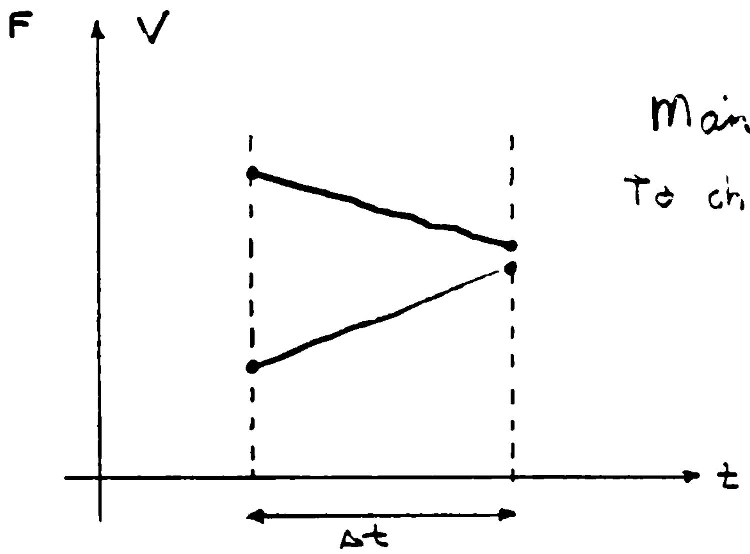
To (Re)bunch coasting beam.

TRP Allways adiabatic

Trapping



Consists of 10 vectors equal in time

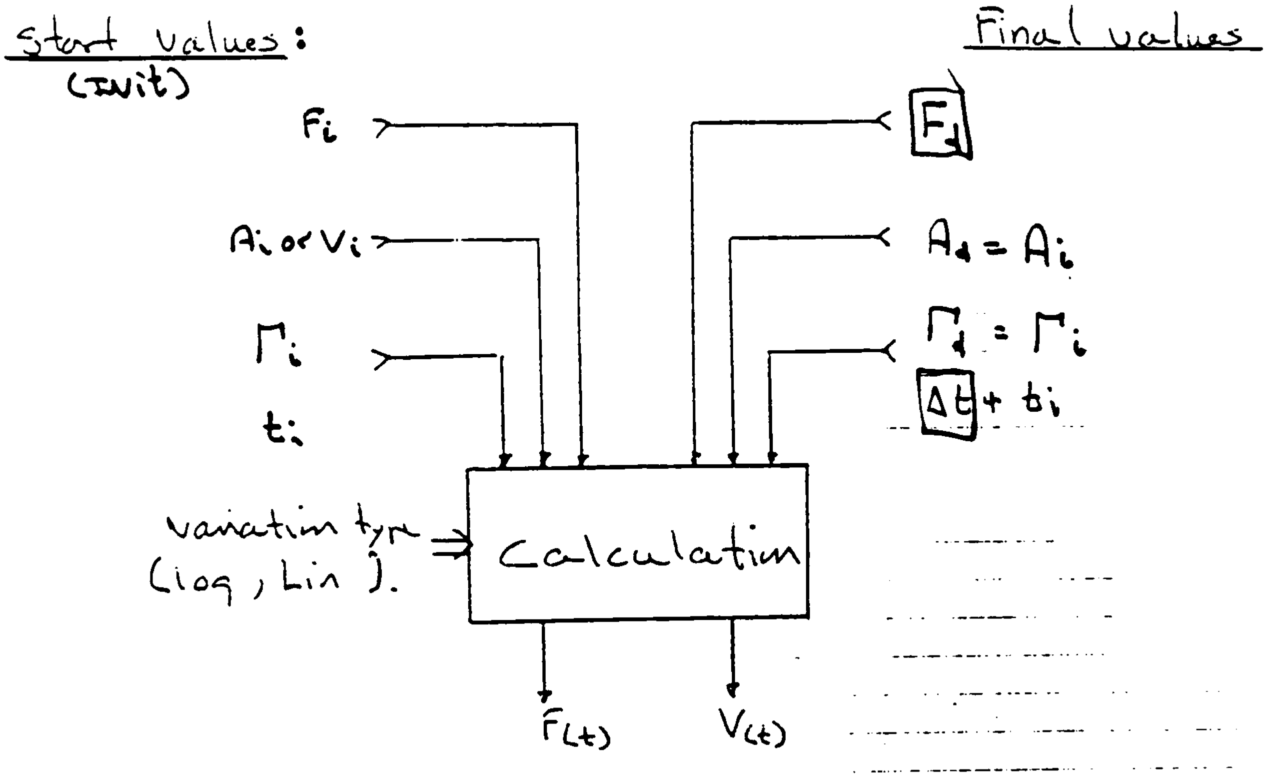


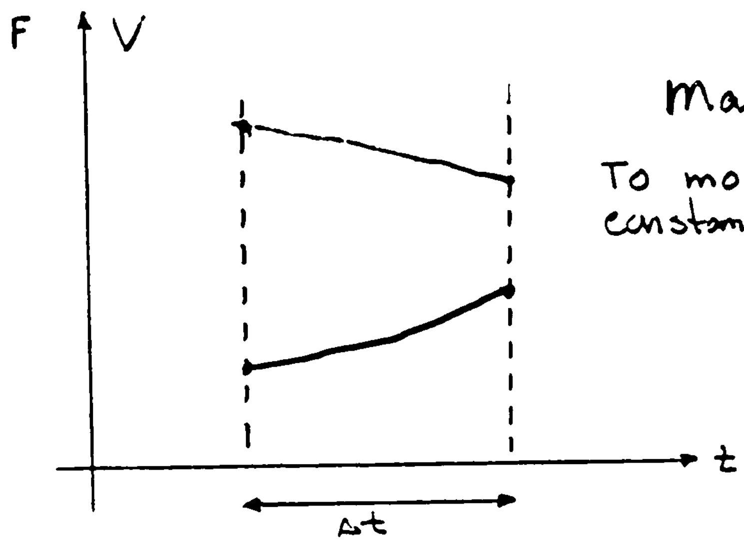
Main purpose :

To change bucket area.

MAT Allways Adiabatic

Matching



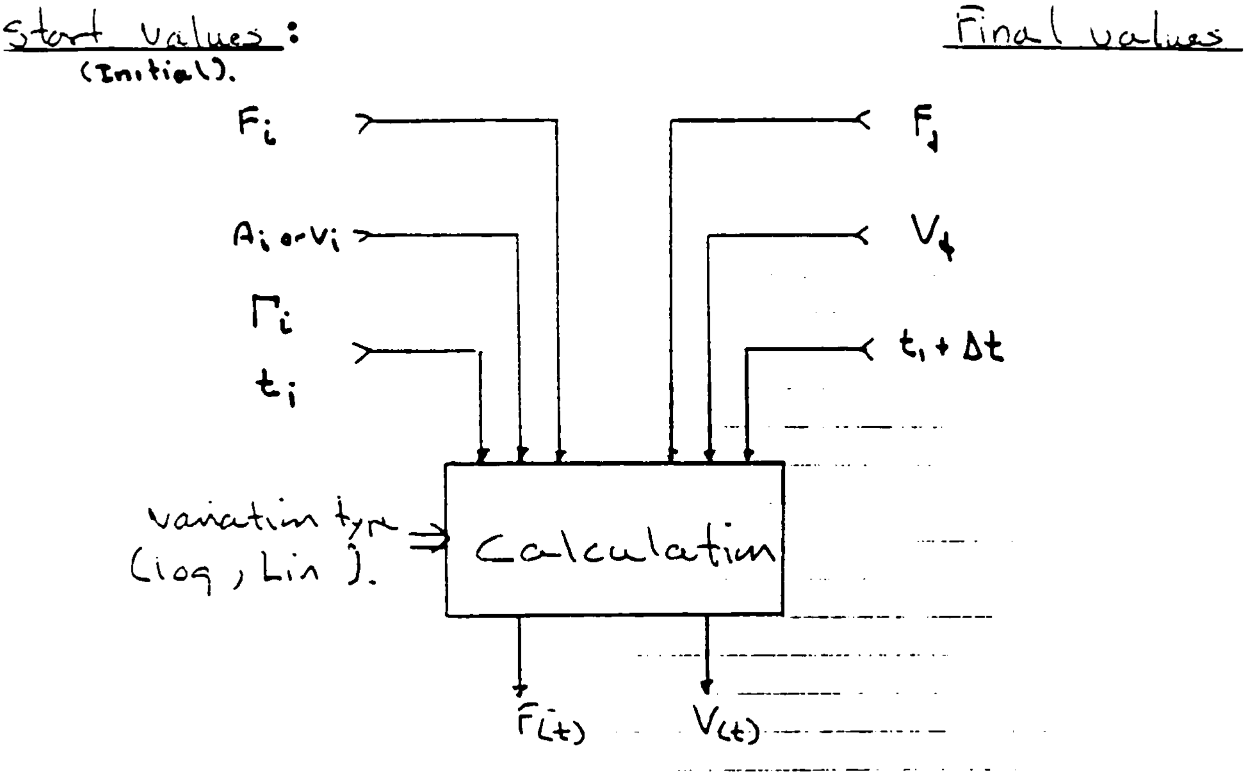


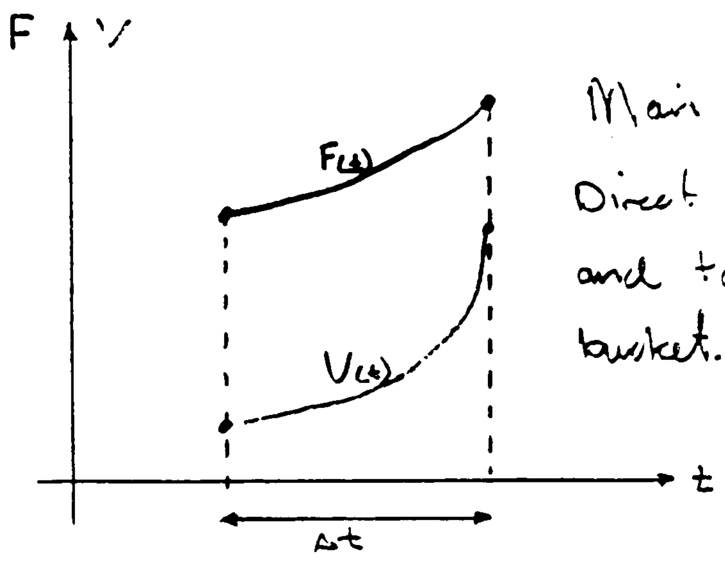
Main Purpose:

To move the beam
constant bucket

MOV

Move

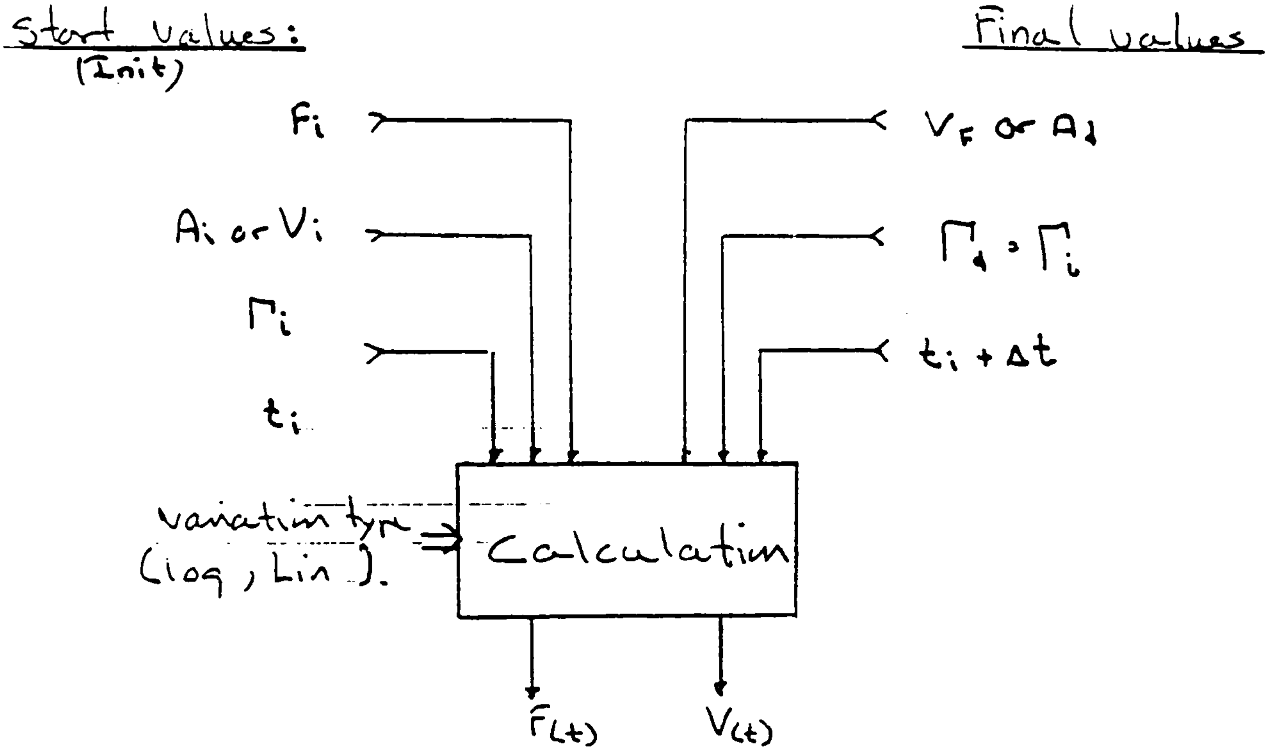


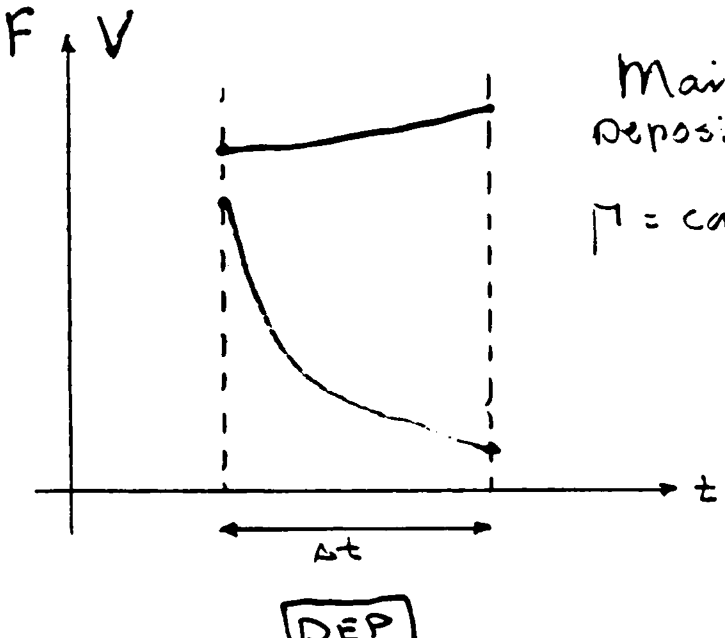


Main purpose is
Direct control of V and F
and to obtain $\Gamma > 1$ [illegible]
bucket.

DHS

Direct Hardware Send





Main Purpose:
Deposit of ? in stocktank

Γ = const, A or V decrease

DEP

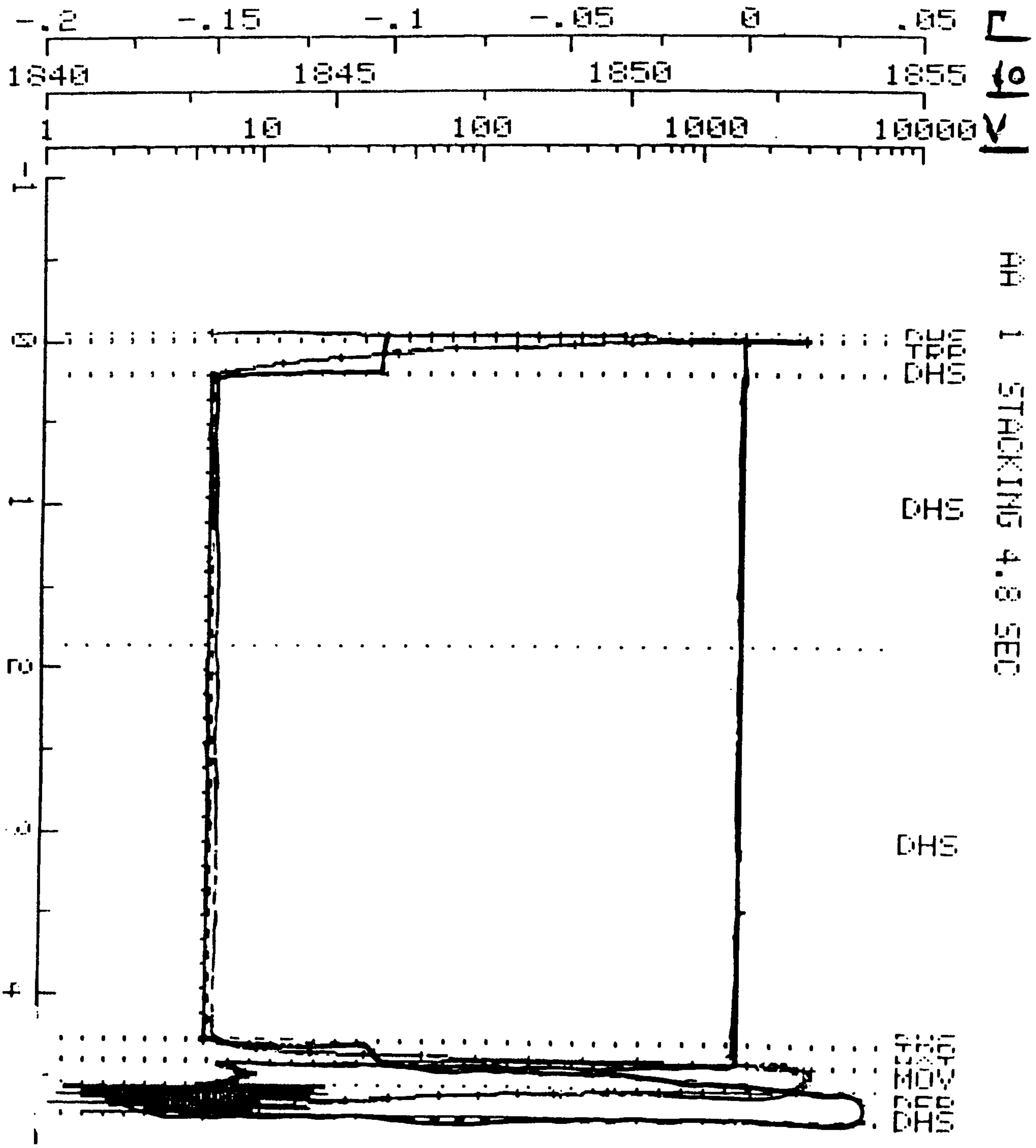
Deposit

AA **1 STACKING 4.8 SEC**

	t−tinj	f		SAVED	USED
PHASE LOCK ON	0	1845.86		91-12-03	92-02-04
PHASE LOCK OFF	.02	1845.86			

SYNC ENABLED

			VALUES AT END OF SEQUENCE						
SEQ	TYPE	Δt	t−tinj	f	A eVs	Γ	V	f_s Hz	VECT
1	INI	0	−.04	1845.86	.2316	0	6	10	1
2	DHS	.03	−.01	1845.86	7.3246	0	6000	331	2
3	DHS	.02	.01	1845.86	7.3246	0	6000	331	3
4	TRP	.2	.21	1845.86	.25	0	6	11	13
5	DHS	.008	.218	1843	.2332	0	6	10	14
6	DHS	1.66	1.878	1843	.2332	0	6	10	25
7	DHS	2.4	4.278	1843	.2332	0	6	10	41
8	DHS	.02	4.298	1845.86	.2316	0	6	10	42
9	TRP	.1	4.398	1845.86	4	0	1789	181	52
10	MAT	1	4.421	1846.4	4	−.15	3406	249	62
11	MOV	.141	4.563	1853.8	4	−.15	2969	217	69
12	DEP	.186	4.749	1854.2	.2	−.15	7	10	82
13	DHS	.009	4.758	1845.86	.2316	0	6	10	83


AA 1 STACKING 4.8 SEC
DHS
DHS
-.2
-.15
-.1
-.05
0
.05
1840
1845
1850
1855
1
10
100
1000
10000
DHS
TPS
DHS
MOV
DHS
-1
0
1
2
3
4

Adiabatic Trapping of unbunched Beam

$$dA/A = \alpha_c \; dt/T_s$$

$$\alpha_c \approx \ll 1 \quad ; \quad T_s = \frac{1}{\nu_s}$$

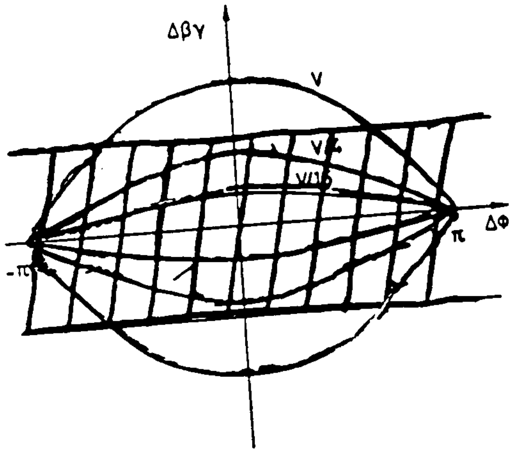


Fig. 24 Adiabatic trapping of coasting beam in growing stationary bucket

95% of the coasting beam will be with 4 evs.

AA

SELECT FILE

ACTIVE FILE SHOWN INVERTED

		LAST SAVED	LAST USED
1	STACKING 4.8 SEC	91-12-03	91-12-19
2	SPS UNSTACKING FUNCTION	91-12-20	92-01-31
3	PROTON STACKER, MODE 7, 1854.9, 6 SHOTS	91-03-26	91-03-27
4	BRING PBARS TO CENTRAL ORBIT	90-11-09	90-11-09
5	EMERGENCY RESTACK	91-06-01	91-06-01
6	PROTON STACKER MODE 2	89-11-14	90-03-26
7	XFER AND DEB. RF - P'S OR PBARS FROM AC	90-06-22	91-12-12
8	FAST PROTON STACKER - MODE 10.	90-04-10	90-09-26
9	TRANSFER RF, MODE 3 OR 4 (DO NOT CHANGE)	91-03-16	92-01-29
10	TRANSFER RF, MODE 3 OR 4 W. LONG. BLOW-UP	90-09-11	90-09-26
11	FAST ION UNSTACKING	90-05-02	90-09-26
12	STACKING 4.8 SEC, 2 eVs	90-05-09	91-05-10
13	PROTON STACKER, MODE 7, 1854.7, 2 SHOTS	90-04-11	90-09-26
14	PROTON STACKER, MODE 7, 1854.8, 4 SHOTS	90-04-11	91-03-27

AA 3 SFS UNSTACKING FUNCTION

	t−tinj	f		SAVED	USED
PHASE LOCK ON	−.873	1854.64		91-12-20	91-12-20
PHASE LOCK OFF	−1.4	1845.73			

SYNC DISABLED

			VALUES AT END OF SEQUENCE						
SEQ	TYPE	Δt	t−tinj	f	A eVs	−	V	fs Hz	VECT
1	INI	0	−1.4	1845.73	.2115	0	5	9	1
2	DHS	.05	−1.35	1855.04	.2362	0	5	8	2
3	TRP	.1	−1.25	1855.04	.6	0	32	21	12
4	MAT	1	−1.064	1854.95	.6	.2	74	32	22
5	MOV	.146	−.917	1854.74	.6	.2	75	33	23
6	MAT	1	−.820	1854.21	1.1	.36	513	86	33
7	MOV	.296	−.523	1846.5	1.1	.4	728	111	43
8	MOV	.045	−.478	1845.73	1.1	.005	140	50	53
9	FIL	.378	−.1	1845.73	0	0	140	50	56
10	TRP	.08	−.02	1845.73	8.4607	0	7996	383	66
11	DHS	.04	.02	1845.73	8.4625	0	8000	383	67
12	TRF	.1	.12	1845.73	.2116	0	5	9	77

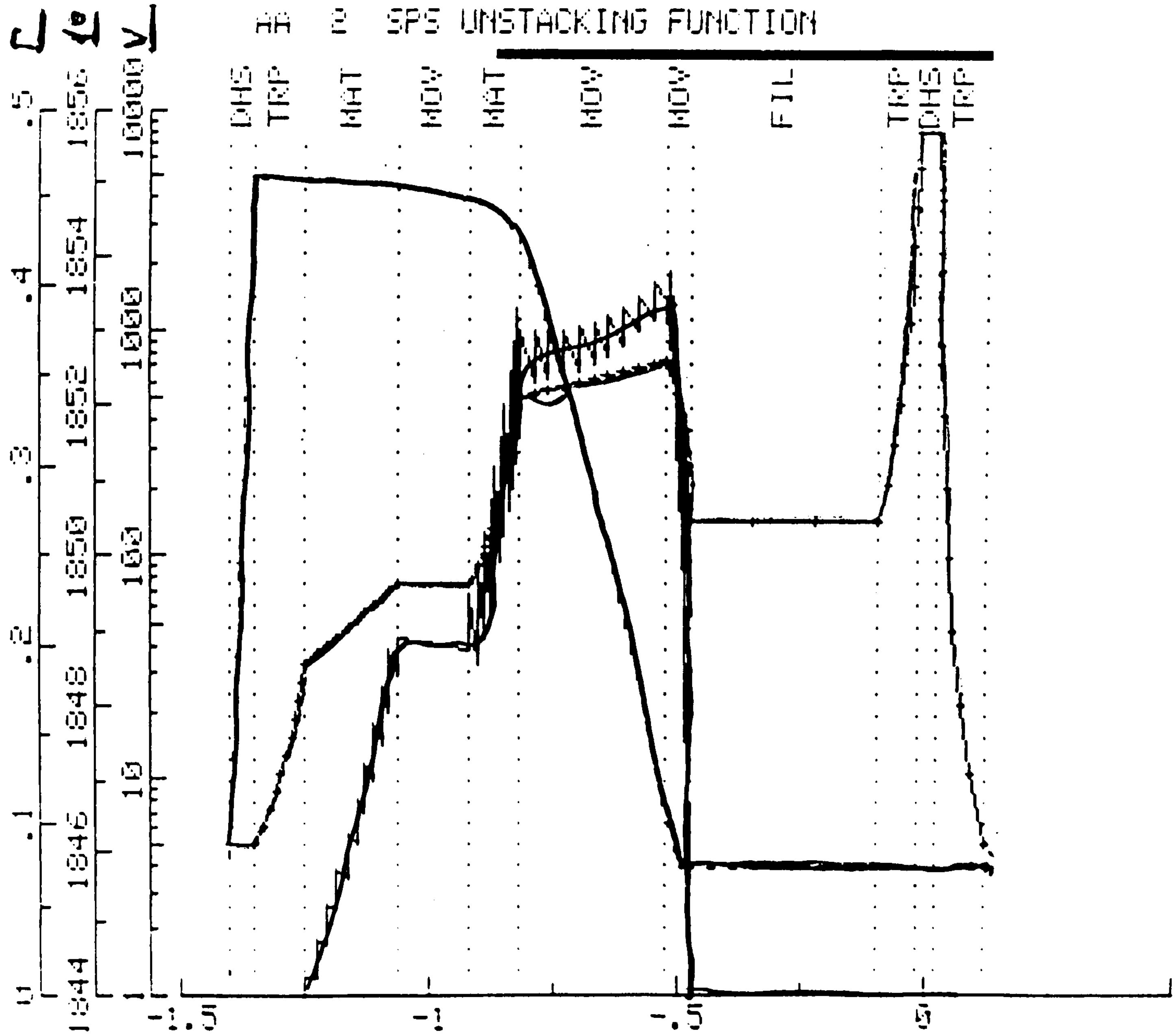
AA 2 LEAR UNSTACKING FUNCTION

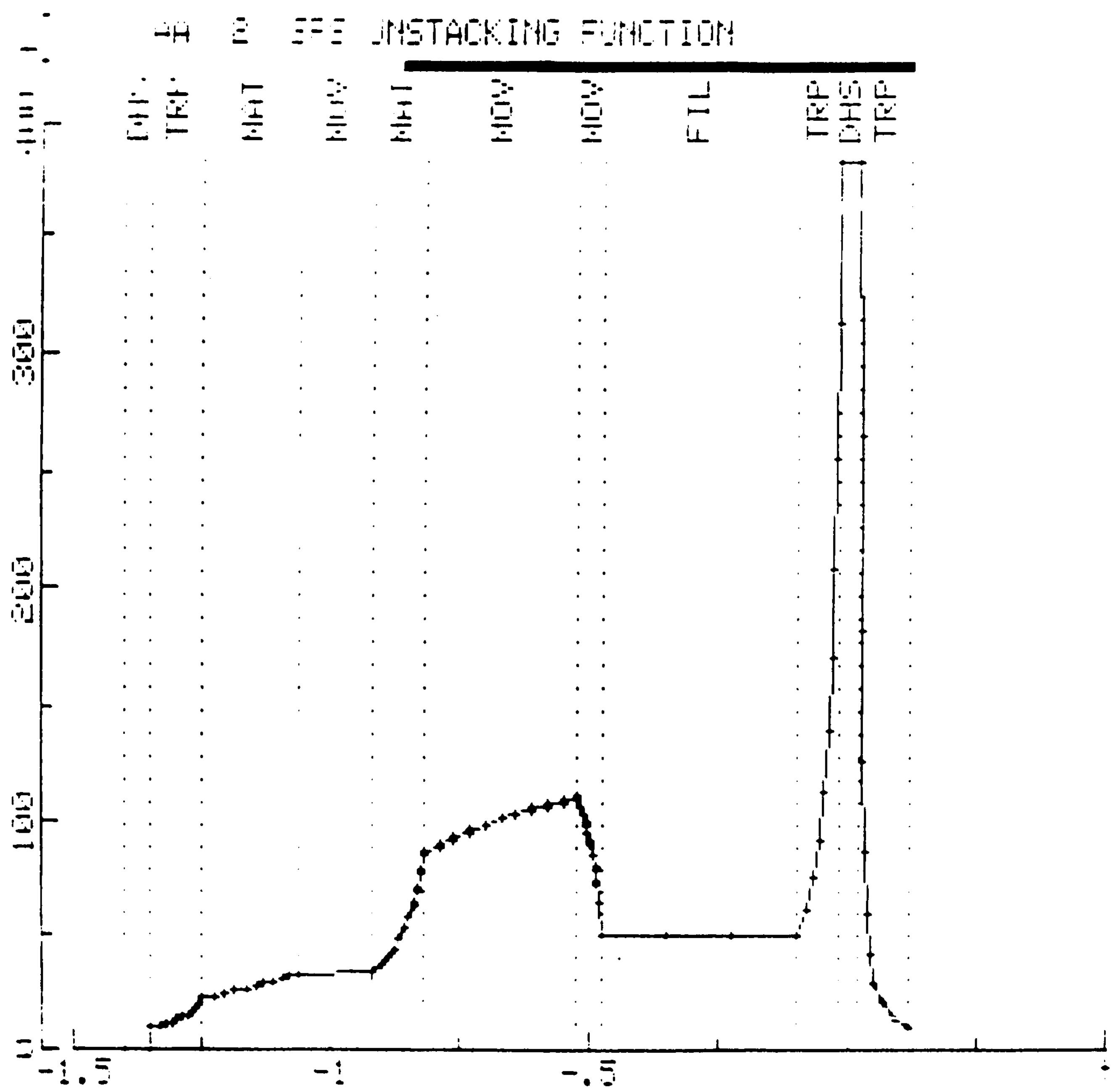
	t-tinj	f
PHASE LOCK ON	-1.486	1852
PHASE LOCK OFF	-2.29	1845.9

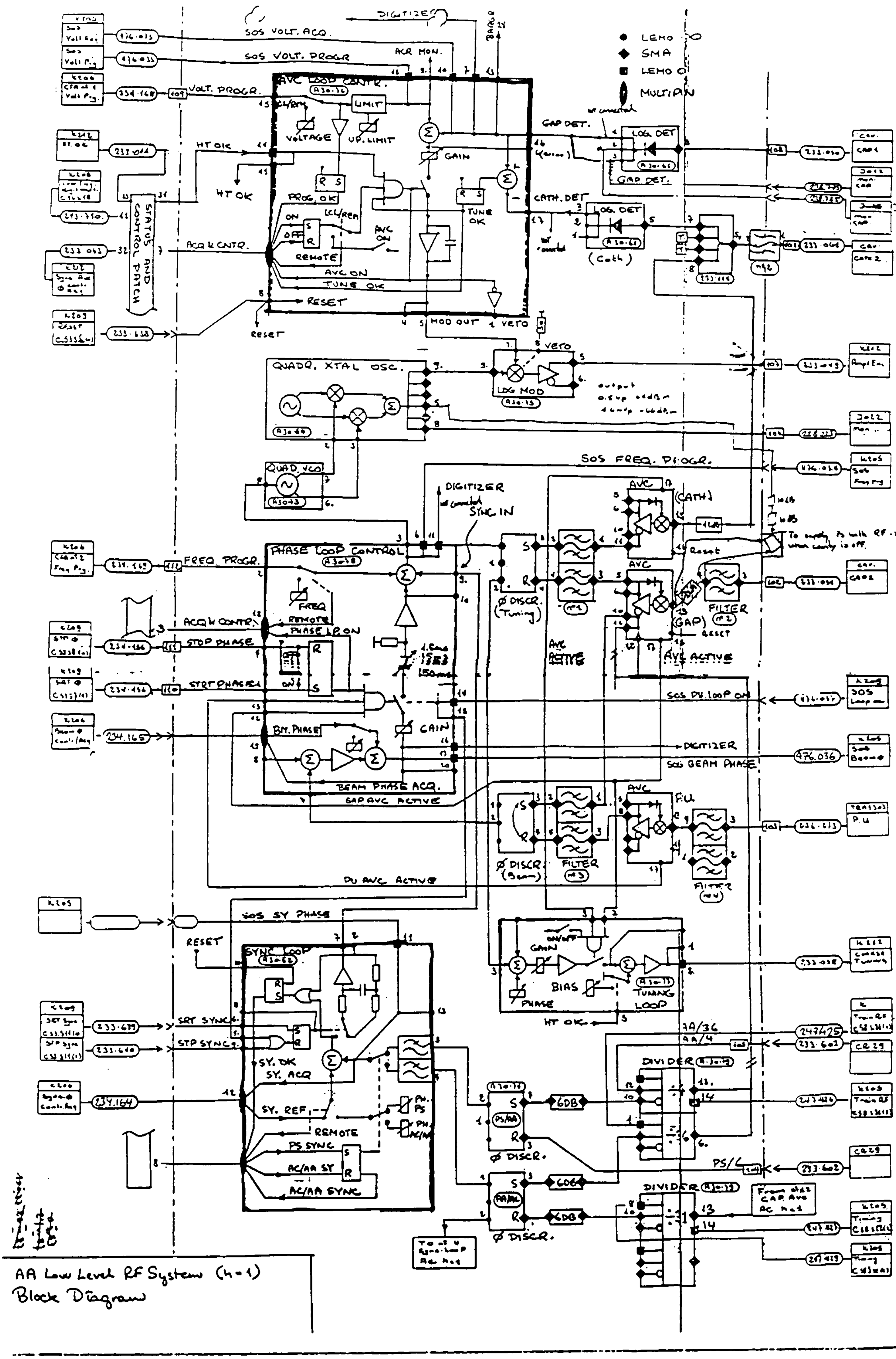
SYNC DISABLED

SAVED	USED
89-12-22	89-12-22

			VALUES AT END OF SEQUENCE						
SEQ	TYPE	Δt	t-tinj	f	A eVs	Γ	V	fs Hz	VECT
1	INI	0	-2.29	1845.9	.2114	0	5	9	1
2	DHS	.05	-2.24	1855.06	.2364	0	5	8	2
3	TRP	.15	-2.09	1855.06	.5	0	22	18	12
4	MAT	.15	-1.899	1854.88	.1047	.745	53	23	19
5	DEP	.219	-1.679	1854	.1047	.745	56	24	33
6	MAT	1	-1.533	1852.75	.2	.745	222	50	43
7	MAT	1	-1.454	1851.43	1.1	.34	539	95	53
8	MOV	.231	-1.223	1846.5	1.1	.34	554	98	57
9	MOV	.054	-1.168	1845.9	1.1	.005	140	50	67
10	FIL	1.068	-.1	1845.9	0	0	140	50	74
11	TRP	.08	-.02	1845.9	8.463	0	8012	383	84
12	DHS	.04	.02	1845.9	8.4564	0	8000	383	85
13	TRP	.1	.12	1845.9	.2116	0	5	9	95


AA 2 SPS UNSTACKING FUNCTION
DHS
TRP
MAT
MOV
MAT
MOV
MOV
FIL
TRP
DHS
TRP
0
.1
.2
.3
.4
.5
1844
1846
1848
1850
1852
1854
1856
1
10
100
1000
10000
-1.5
-1
-.5
0


JNSTACKING FUNCTION
TRP
DHS
TRP
FIL
MOV
MOV
MAT
MOV
MAT
TRP
400
300
200
100
0
-1.5
-1
-.5



AA Low Level RF System (h=1)
Block Diagram

Syncronisation Between AA/AC

$$\frac{F_{AA}}{F_{AC}} = \frac{1846.1 \text{ kHz}}{1589.5 \text{ kHz}} = 1.16143$$

$$\frac{36}{31} = 1.16129 \quad \text{OR} \quad F_{AA} = \frac{36}{31} \times 1589.5 = 1845.9$$

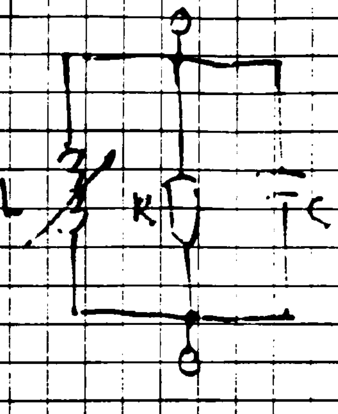
$\frac{F_{AC}}{31} = 51.2742$ kHz $\Rightarrow$ The 2 RF systems are in phase every 19,5 μs

Syncronisation between AA/PS

$$\frac{F_{PS}}{6} = 461.456 \text{ kHz}$$

$$\frac{F_{AA}}{4} = \frac{1845.865}{4} = 461.466 \text{ kHz}$$

Cavity



$$F_{RES} = \frac{1}{\sqrt{LC}}$$

$$Z_{res} = R$$

$$Q = \frac{R_P}{X_{RES}} \Rightarrow R_P = X_{res} \cdot Q$$

For AA H=1 And AC H=1 the cavity is tuned into resonance by biasing [illegible] Ferrites located inside the cavity, with ≈ 50 Amps and thereby change the total inductance.

To avoid longitudinal instabilities (low shunt impedance (...), and allow for maximum Power transfer to the cavity, the cavity must be in resonance

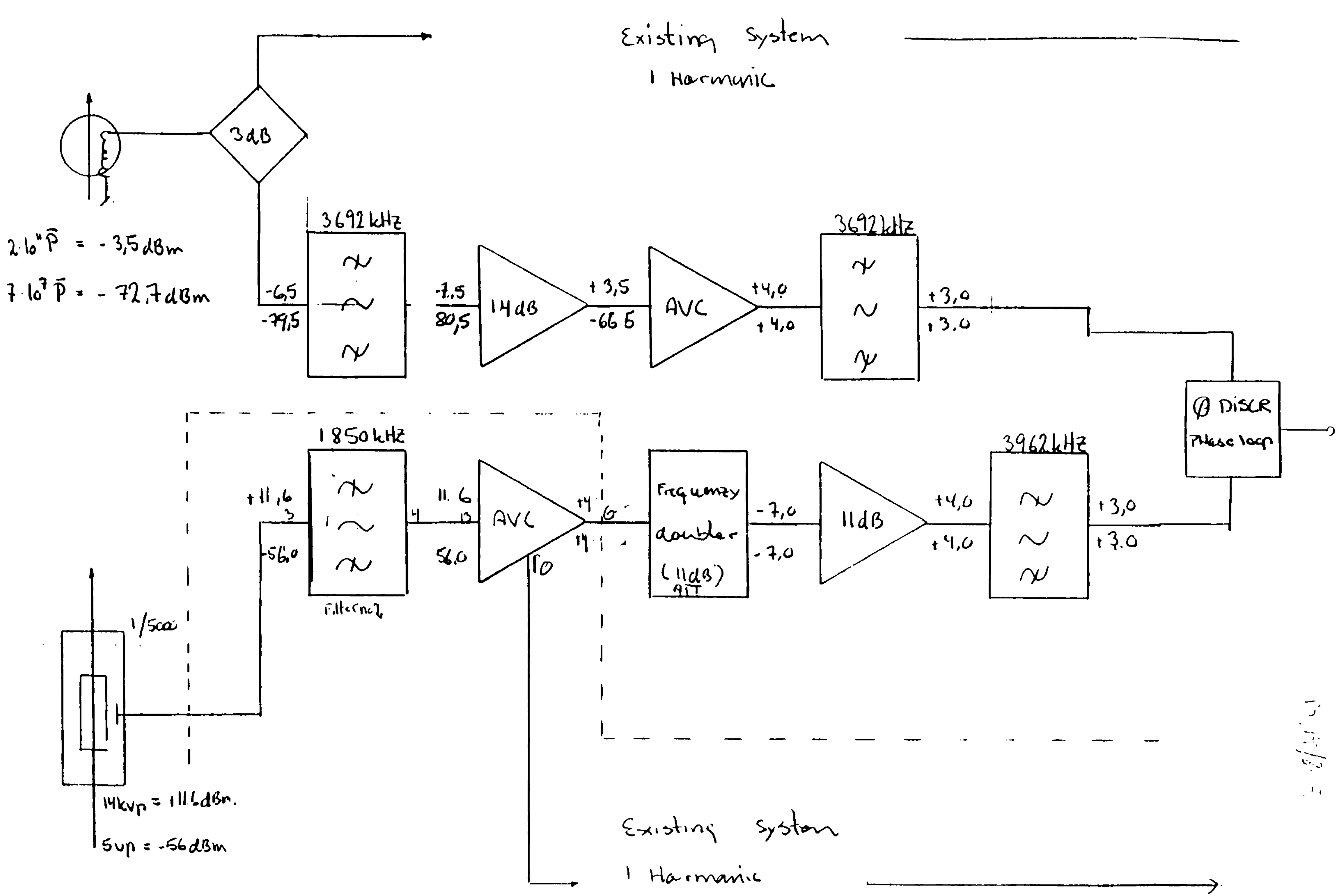
For tuning the H=6 cavity a Bs Trim capacitor is used

BEAM PHASE, SYNC PHASE + FREQUENCY 1990-02-20-18:30:49

		BEAM PHASE OFFSET,deg	NOTE	SYNC PHASE OFFSET,deg	NOTE	FREQ. kHz	NOTE
	h=6, CAV.1			+60	1	9536.868	1
AC	h=6, CAV.2			+45	1		
	h=1, FROM AA	21	1	+13.7	1,2	1589.478	1,4
	h=1, FROM PS	9	1		3	1589.414	1,5
	FROM AC	-35	1	30	1,2,8	1845.845	1,7
AA	FROM PS-LOOP	-80	1	61.8	1,2	1845.76	1,6
	FROM PS-DIR.	-35	1	-175.0	1,2	1845.76	1,6
	PBAR EJECTN.					1845.897	2

NOTES 1. SET BY THIS PROGRAM
2. SET BY RELEVANT COHERENT OSCILLATION PROGRAM
3. NO SYNCHRONISATION PROVIDED
4. BUNCH ROTATION FREQUENCY DIVIDED BY 6
5. INFLUENCED BY ENERGY LOSS IN AIR ETC.
6. PS REVOLUTION FREQUENCY *4
7. BUNCH ROTATION FREQUENCY *6/31
8. FOR PROTONS; 29 DEGREES LESS FOR ANTIPROTONS

PHASE OFFSETS ARE SENT TO HARDWARE BY THE MODE PROGRAM (OR WHEN SET BY THIS PROGRAM, PROVIDED THE MODE IS CORRECT)
FREQUENCY VALUES ARE USED BY RF FUNCTION DEFINING PROGRAMS (h=1)



Existing system
1 Harmonic
3dB
$2 \cdot 10^{-11} \bar{P}$ = -3,5 dBm
$7 \cdot 10^{-7} \bar{P}$ = -72,7 dBm
3692 kHz
-6,5
-79,5
-7,5
80,5
14 dB
+3,5
-66.6
AVC
+4,0
+4,0
3692 kHz
+3,0
+3,0
Ø DISCR
Phase loop
1850 kHz
+11,6
-56,0
Filtering
11.6
56,0
AVC
+4
14
10
Frequency
doubler
(11dB)
ATT
-7,0
-7,0
11dB
+4,0
+4,0
3962 kHz
+3,0
+3,0
1/500
14kvp = 111.6 dBm.
5vp = -56 dBm
Existing system
1 Harmonic

RF HARDWARE CONTROL (n=1,AA)

LEVEL 1	AMPLIFIER EN1	
LEVEL 2	COARSE TUNING	
PHASE LOOP	DOORS CAVITY	
AVC	WATER COOLING FERRITES	
SYNC	VACUUM	
		WATER COOLING
VOLT.PROGR.		AIR COOLING
TUNE		FILAMENT 1
SYNC	FINAL STAGE	FILAMENT DELAY
		FILAMENT 2
		ANODE VOLTAGE
		GRID 1 VOLTAGE
		GRID 2 VOLTAGE
	DRIVER	EL55 VOLTAGE
		FILAMENTS
		CATHODE VOLTAGE
		GRID 2 VOLTAGE

RFC(1,STAQ) 170 CAMAC ERROR (LOOK AT DETAILS BY PROP. CAMERR)