RF BOOK

RF Note 68

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Phase and Amplitude Control for 1 and 3 Operation

Introduction

As a result of computer analysis, previous operating experience with the K50 cyclotron and some modeling, it has become obvious that different criteria exist for the two modes of phasing for the K500 and K800 three dee cyclotrons. Further, it is also obvious that in order to achieve compatibility of the various modules involved in servoeing phase and amplitude control, certain modifications to our existing plan should be made. This paper will review the technical problems involved, present various schemes for implementing the final hardware, and recommend modifications to our existing hardware. A final decision as to how to actually connect things will await various tests on our high Q three phase model which is to be installed on the power supply balcony.

Discussion of the Problem.

Unfortunately, intuition, or seat of the pants thinking has not been very useful to me. But the results of model testing and computer calculations agree and I will try to succinctly present their results. For 3ϕ operation the criteria are clear: each dee amplitude can be controlled by the regulator controlling drive to that dee, and each dee phase can be controlled by its fine tuner to acheive zero degrees phase shift between the incident power and the stem current. Although, because of the dee to dee coupling capacities, there is not complete orthoganality as to what happens to other dees when one dee is tuned or amplitude regulated, it seems that this orthoganality is about .8, where 1 would be complete orthoganility. So we are happy with our present scheme for 3ϕ operation. Philosophically we can say that 3ϕ operation is not an unstable mode, it certainly isn't a stable mode; it is just a mode of controlability.

1 phase operation is radically different. It is a stable mode. The amplitudes can vary wildly, but the phases are always within $\pm 1^{\circ}$ even though dees are detuned. And changing the drive to one dee changes all amplitudes, but hardly effects the phases at all. Therefore, the criteria for tuning and amplitude regulation are radically different than for 3ϕ operation. The clue as to how to accomplish amplitude and phase regulations is to be found by studying what happens if we had only one transmitter.

With only one transmitter, for 3ϕ operation we can adjust the dee tuners to acheive -120, 0, +120 degree operation, but have no control of the amplitudes, which is why we have three transmitters! But for 1ϕ operation, one transmitter is enough to accomplish both; since the phase is always going to be ok, the fine tuners, instead of adjusting phase, can adjust the relative amplitudes. Seat of the pants thinking shows why. Take the K50 cyclotron rf system for example: If dee #2 is tuned too high it looks inductive to dee #1 and the coupling capacitor in series with this inductance can cause dee #2 voltage to be arbitrarily higher than dee #1 voltage. Tuning dee #2 on the low side results in a lower voltage for dee #2.

Hardware

Fig. 1 shows the elements of the 3 dee rf system relevant to this paper. Table I defines the various quantities appearing in Fig. 1. Fig. 2 and 3 are transparencies to be overlaid on Fig. 1 to show how to make connections for 1ϕ and 3ϕ operation. The scheme shown in Fig. 2 is not unique and later we may change this. The purpose of showing these schemes is to reveal how we should modify our existing hardware in order to be able to implement them.

V1,ϕ1; V2,ϕ2, V3, 3	dee voltages and instantaneous phase relative to $\phi\emptyset$, the phase of F2.
$\overline{V1}$, $\overline{V2}$, $\overline{V3}$	Peak detected normalized (calibrated) dee voltages.
W1, P1; W2, P2, W3, P3	incident dee power and phase
$\overline{W1}$, $\overline{W2}$, $\overline{W3}$	Peak detected, normalized, incident power
$\overline{V1}$, $\overline{V2}$, $\overline{V3}$	Peak detected, normalized, reflected power
$\overline{\phi 1}$, $\overline{\phi 2}$, $\overline{\phi 3}$	Phase detector outputs of difference in phase between ϕ(N) and P(N)
$\overline{P1}$, $\overline{P2}$, $\overline{P3}$	Analog commands to the fine tuner servoes
C1, C2, C3	Analog commands to the amplitude regulators
D1, D2, D3	RF input to amplitude regulator
Q1, Q2, Q3	Analog commands to the fast phase servoes.

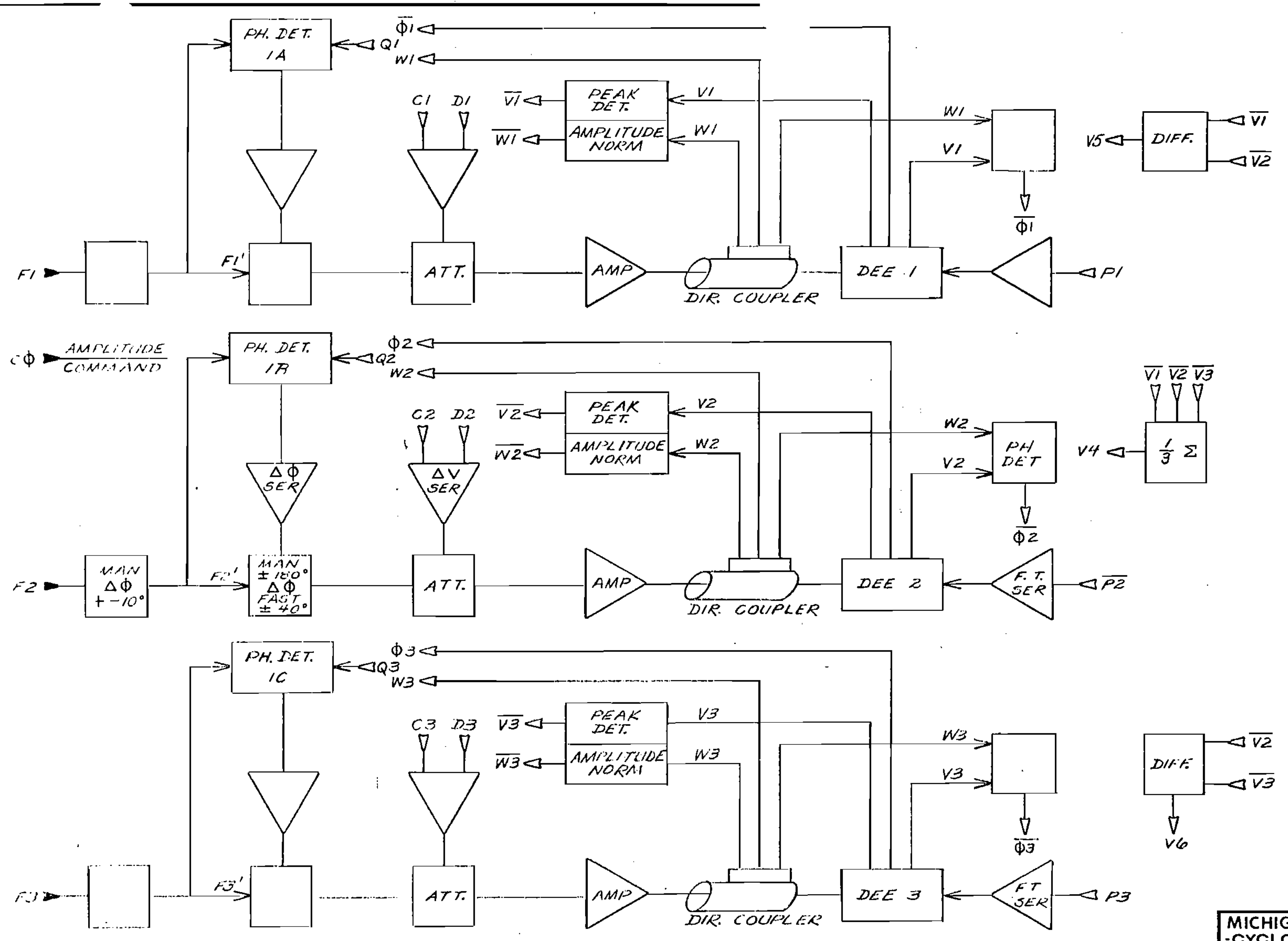
$\overline{V4} = (\overline{V1} + \overline{V2} + \overline{V3})/3$

$\overline{V5} = \overline{V2} - \overline{V1}$

$\overline{V6} = \overline{V2} - \overline{V3}$

$\overline{X1}, \overline{X2}, \overline{X3} = \overline{V1}/\overline{W1}, \overline{V2}/\overline{W2}, \overline{V3}/\overline{W3}$

TABLE 1



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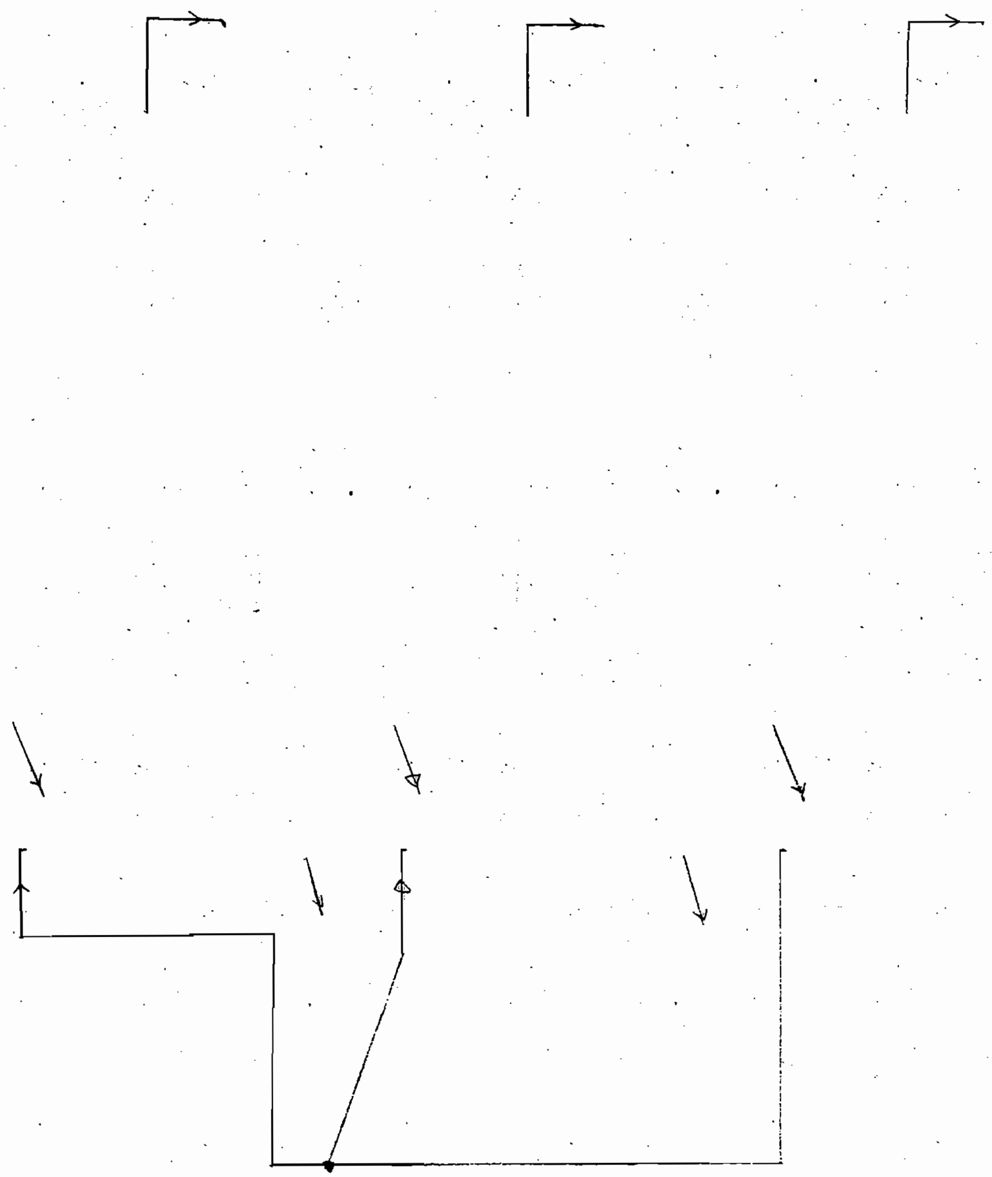
BLOCK DIAGRAM	SCALE	DRN BY BROWN
		APPR'D
TITLE: PHASE & AMPLITUDE REGULATION, 1Φ & 3Φ		
DATE: 11/11/80	SHEET: 1 OF 3	DRAWING NO.: 3-1-2... 1A-1-B
REV.		



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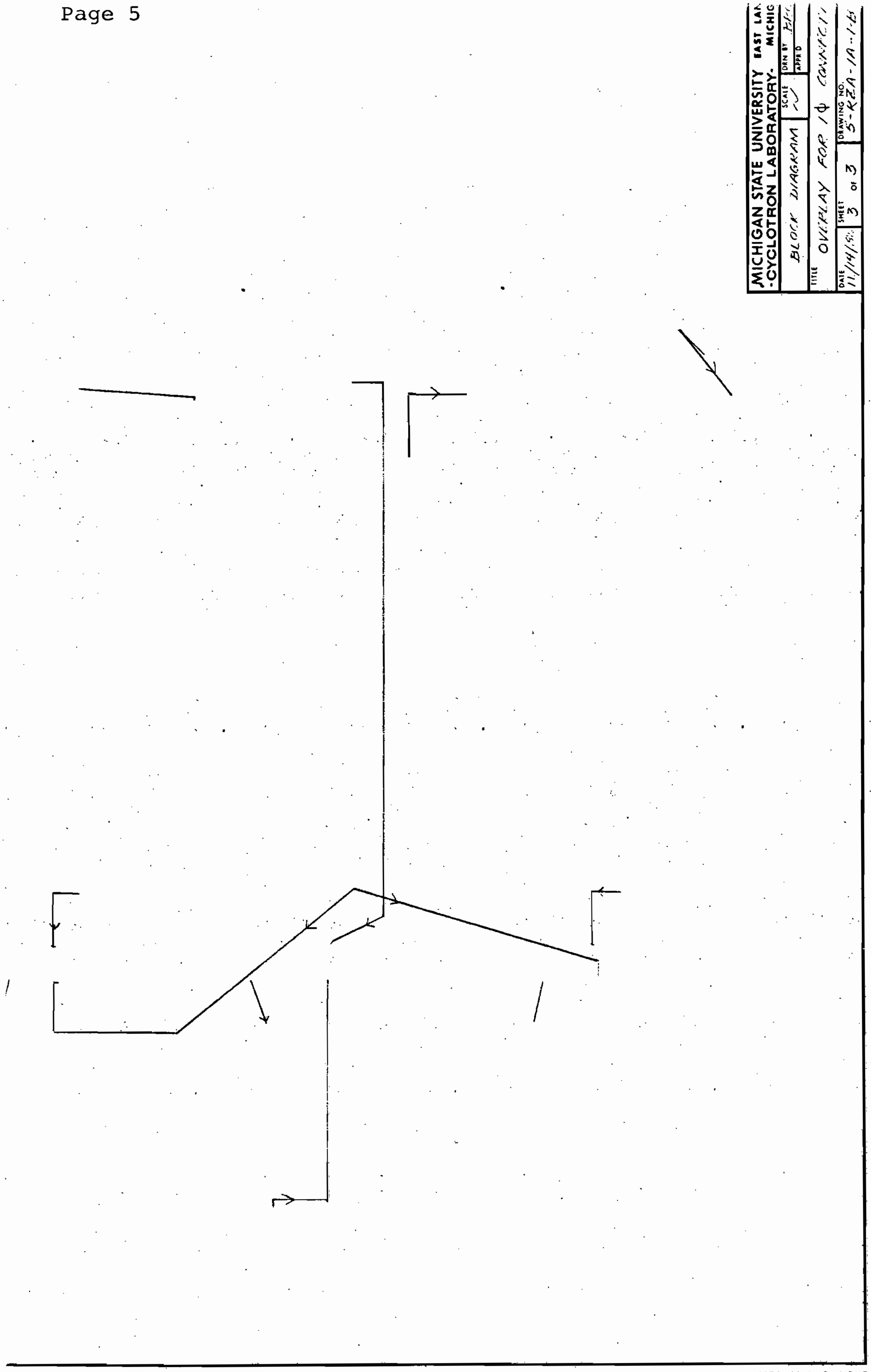
BLOCK DIAGRAM

SCALE	DRN BY	APP'D
~	BPC	

TITLE: OVERLAY FOR 3φ CONNECT

DATE	SHEET	DRAWING NO.
11-14-80	2 OF 3	5-PZA-1A-1-B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BLOCK DIAGRAM
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Studying the connections revealed by the overlays it becomes apparent that the following modifications should be made to our presently conceived hardware:

1. There should be a coaxial switch to substitute W1 for V1 and W3 for V3 into the #1 phase detectors.

2. There should be a DPDT switch added to amplitude regulators A & C so that C1 and C3 can be switched from C$\phi$to $\overline{W2}$, and D1 and D3 switched from $\overline{V1}$ and $\overline{V3}$ to $\overline{W1}$ and $\overline{W3}$

3. There should be a SPDT switch at the input of A&C fine tuner phase servoes to substitute $\overline{\Phi 1}$ and $\overline{\Phi 3}$ to V5 and V6.

4. There should be a APDT switch on B amplitude regulator to substitute V4 for $\overline{V2}$.

5. A module to produce V4, V5 & V6 should be built.

6. Amplitude regulators A & C should have another SPDT switch (possibly making the switch in 2 above be a TPDT) to change the frequency roll off condenser in the servo amplifier to a different value.

The High Q Model

Most of the parts for the high Q 3 dee model have been found and assembled on the power supply balcony. Before we can make meaningful tests with it we must acquire or build the following hardware;

1. 3 transmitters. Although it would be better to buy 3 100 watt tetrodes, it is cheaper to use our 4CW2000 A tubes destined for the K500 drivers, as we already have them. Still, they must be mounted in boxes.

2. We must purchase 3 bidirectional couplers. These will cost about $300 each.

3. We must build the complete final set of phase detectors, fine tuner servos and voltage regulators.

4. We must add capacity plates to the "dee" boxes to bring the frequency down. It is estimated that all this will take two to three months.