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Phase Spread in the High Level RF System

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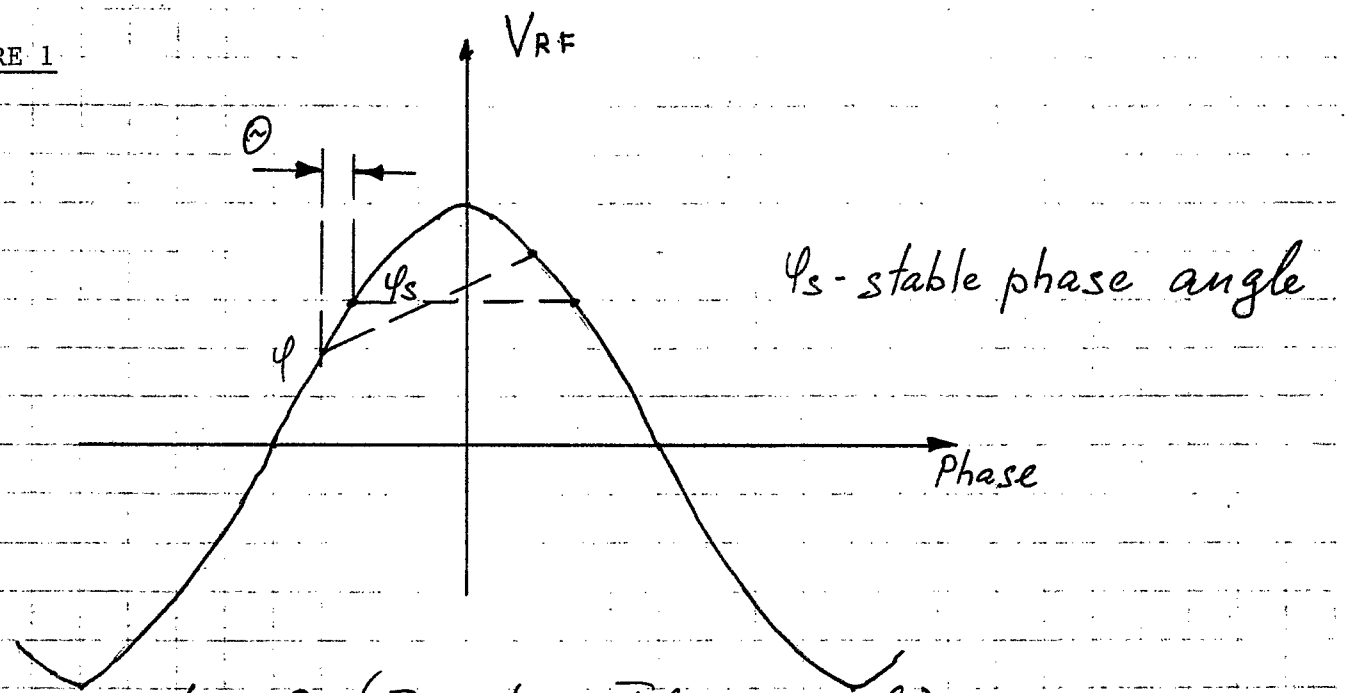
Subject: Phase Spread in the High Level rf System

As part of the new phase detectors/directional couplers installation, studies to measure phase spread between rf stations were performed.

The step in the gap voltage (up or down) at transition is attributed to the difference between the phase of the station and the average of all stations. Since the jump at transition is the same for all the rf stations, the relative phase of the stations with respect to the beam will change at transition. As seen at Fig. 1, a station with a phase lower than the average, phase before transition will have a phase higher than average, and hence more beam loading and a step down in gap voltage after transition.

FIGURE 1



$$V_0 = R_T\left(\underline{I}_{generator} - \underline{I}_{beam} \cdot \sin\varphi\right)$$

before x-ition: $\varphi = \varphi_s - \Theta$; $\sin\varphi = \sin(\varphi_s - \Theta)$

after x-ition: $\varphi = (\pi - \varphi_s) - \Theta = \pi - (\varphi_s + \Theta)$

$$\sin\varphi = \sin[\pi - (\varphi_s + \Theta)] = \sin(\varphi_s + \Theta)$$

The main goal in the design of the new phase detector was to make it frequency and amplitude independent. An additional feature of the new unit is a provision to adjust the angle of the impedance of the cavity. This changes the angle of the gap voltage with respect to the phase of the drive, which gives us an ability to move all the rf stations as close as possible to the same phase angle.

An HP5371A frequency and time interval analyzer was used to measure the phase shift between a reference rf station (station B), and the nine remaining ones. Since the analyzer cannot be externally riggered, rf switches were used to gate on rf signals between the downstream cap dividers, available at the injection console, and the input to the analyzer at different times after T0. Data was taken three times. The first set of data (plot #1) was taken prior to the installation of the new phase detectors. The reference signal was plugged into "A" input of the analyzer.

Some difference in the behavior of high letter stations from low letter stations can be noticed in the plot #2. Low gain of the power tubes in driver "A" which drives low letter stations were the culprits. Data was taken after replacing old tubes in the driver and replacing old directional couplers and phase detector in station "D" (plot #3).

When the second set of data (plot #2) was taken, station "D" was still running on the old directional couplers and the old phase detectors.

It can be seen from the plots below that at least a factor of two reduction in the phase spread with the new phase detector was achieved.

After installation of the new phase detectors, we were able to get rid of the steps in the gap voltage after transition.