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REVOLUTION HARMONIC REJECTION

AA STACK CORE SYSTEM

by

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Introduction

The stack core betatron cooling uses differencing pick-ups to detect beam betatron oscillations. The pick-up outputs top and bottom or left and right are in fact differenced in external hybrid networks which reject any signals common to both inputs (the common mode), such as the revolution harmonic, by the order of 30db. Other unbalances however are possible, due to the beam not being centred, or lack of transmission balances through the microwave paths, etc.. These were regarded for a time as background annoyances which should be understood and fixed, partly so that the fast betatron cooling for the ACOL project should not be plagued by these problems, since power wasted in the revolution harmonic could not be afforded there.

Since Flemming Pedersen observed the effect of the revolution harmonic on the cooling during stacking though, the problem has become more immediate. Flemming noted that when particles are being drawn towards the stack core centre, there can be heating of the core sidebands when the revolution frequency of incoming particles is close to the core sideband frequencies.

Common mode signals.

We installed a new betatron pick-up in Section 1 in the January shut-down of 1983 in order reduce the tendency to overlapping of revolution harmonic with sidebands, experienced from the beginning of the AA, due to the high dispersion (≈9m) in the original position in Section 5. We also hoped that cross-talk from the pre-cooling kickers in Section 3 would disappear, which it did. Looking however at the betatron Schottky signals over several hundred MHz, we saw very strong revolution harmonic signals, which unfortunately had not disappeared. Photos taken in March 83 (Fig.1) and in May over a narrower band (Fig.2) show relatively smooth amplitudes with frequency in the H plane, but ragged amplitudes for the V plane, a pattern which has persisted ever since.

The first attempts to modify the revolution harmonic amplitudes were via the trim control and vertical bumps, which worked as expected.

Next we checked the electrical balance through each of the slot box circuits from upstream to downstream feedthroughs and through carefully cut foam cables, using the network analyser, which showed no unbalance provided that we could assume mechanical and electrical symmetry at both ends of the pick-up. At the next opportunity, during the July shut-down, we approached the output balance through time domain measurements and succeeded in trimming the electrical lengths from hybrid terminals to first insulating support on the pick-up coupling line to a mm or so, a few degrees of phase. This work was done in order to be able to eliminate the possibility of electrical unbalances due to length errors, and had no noticeable effect on the common mode signals.

Another possibility suspected already from the RF measurements on the PU tank was that the mediocre match of the feedthroughs was producing reflection losses which were not necessarily identical in top or bottom lines at all frequencies, or left and right lines. This could produce unbalances which can cause big differences in common mode rejection when near balance (Figs. 3,4 &5 show the layout, the transmission measurements on the slot lines, and the relation between unbalance and rejection). What was unsatisfactory about this explanation was that we could not see any reason why it should not apply equally to H and V, whereas we had this marked difference between signals varying slowly with frequency in the H case and much faster for V. Nevertheless, on the assumption that the poor match of the slot lines, including feedthroughs, could not be helping things, we placed an order in March 1983 just after the shut-down for some Type N Ceramaseal feedthroughs which had a better match, particularly at the top of the 1-2GHz band.

Most of our effort later in 1983 and early '84 was concentrated on improving the filters in order to cope with the large phase differences between sidebands, but photos in the log for March 1984 show the same behaviour as before of H and V. [Later in the year the conversion to single kicker working dominates the log entries.]

During the Jan/Feb shut-down of 1985 we began to investigate another possibility, namely that the discontinuities in the beam chamber upstream and downstream of the PU 1, which were more abrupt than we had realised, could be giving rise to resonant behaviour in beam-induced wave motion in the chamber. We had discovered belatedly that there were a TV screen and viewing window, and associated beam chamber interruptions, a metre or so upstream of PU1, (providing among other things a coupling path into the pick-up from outside the vacuum chamber), and bellows discontinuities elsewhere, as well as a gate sector valve downstream a short distance (Fig.6). The possibility of resonant reflections from these discontinuities suggested a mechanism which could distinguish between H and V behaviour, since the pick-up chamber and some of the beam chambers in the vicinity are much wider than their height - for example the PU is around 300mm wide but only 60mm high, which means that from 1 to 2 GHz there can only be waveguide propagation with a vertical E vector (a vertical E is permitted by the width dimension above 500MHz, whereas a horizontal E vector requires 2.5GHz to start propagating). In fact the design aimed at parallel plate transmission line in the chamber, with negligible current flow and reflection from the side-walls, which would discourage a horizontal E vector over a wide frequency band.

In order to test the resonance conjecture, and to learn something about the leakage, we placed a dipole antenna near the TV camera window, and fed it from a Varian TWT driven by a comb generator, producing simulated revolution harmonics at a spacing available from the equipment of 10MHz instead of the harmonic spacing of 1.855MHZ, and looked at both the horizontal and vertical Schottky signals in the ACR. Sure enough we saw good strong signals getting into the cooling pick-ups from the outside, resulting in very similar signatures to the beam Schottkys in V and H, i.e. fast variations in V, slower in H (Figs.7&8). The average density of resonances can be related to the volume of a cavity resonator and the frequencies by $dN/df=8\pi Vf^2/c^3$, which gives the density above frequency f (derived from Moreno p.218), and yields numbers around 3MHz average spacing per mode for the guessed dimensions affecting PU1. We should have liked then to have done something about damping the chambers with resistors, but it was not possible to fit this into the vacuum programme. The flared-out end transitions of the pick-up chamber can also produce reflections and resonant modes in principle, but less closely spaced, more akin to the feedthrough and line pattern with the order of 100 MHz spacing.

In March 1985 we made some attempt to balance the H signals with fractional db attenuators improvised from Type N double female adaptors. This did not seem very interesting to pursue at the time as it can only give flat corrections with frequency, whereas the causes are anything but flat. A feedback correction system, using an unused sum port at the hybrid output, was also suggested. This would have to be carefully balanced and maintained, and adds complication, but is not excluded as an alternative to trim adjustments, preferably after we have exhausted all attempts to attack the causes.

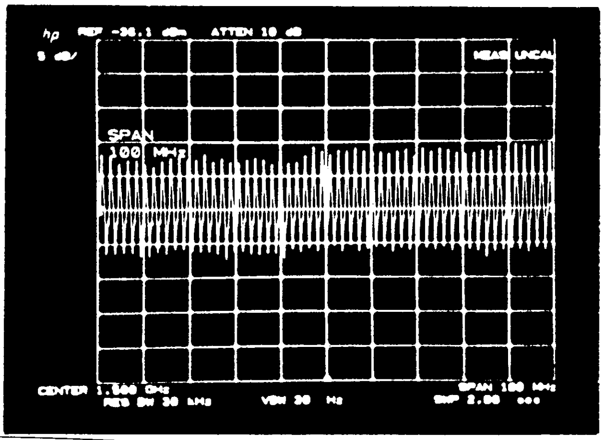
Adjusting the beam horizontal trim to pass through the electrode centre of course has always had a good effect, but this is not necessarily consistent with maximum machine acceptance and anti-proton yield, so in the 1985 summer shut-down the PU 1 tank was moved bodily by 1mm towards the ring centre in order to bring the two requirements closer together.

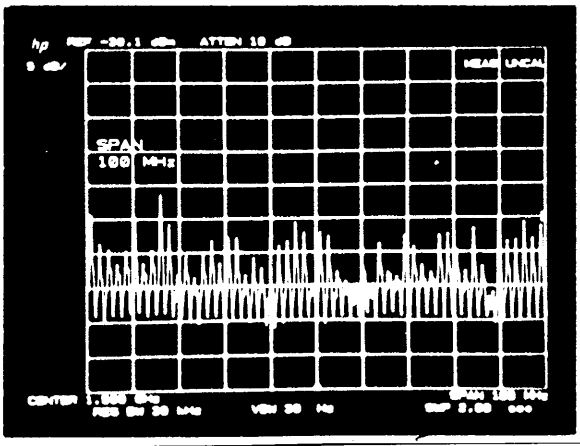
In the short shut-down in late August of 1985, we fitted the Ceramaseal type N feedthroughs ordered in 1983, but apart from a slightly improved behaviour at the top of the band, this had little effect on the common mode signals. This confirmed however what we had suspected, namely that the bad match, with return losses less than 10db, and correspondingly large transmission unbalances, is due also to imperfections in the rigid coaxial lines and fittings. If we were to fit the new Ceramaseal SMA feedthroughs to the present coaxial lines, the improved match of the new feedthroughs would probably be swamped by the reflections in the lines and connections, so the intention is to change also the coaxial lines for solid-dielectric, UHV-compatible cable, similar to semi-rigid in appearance, as well as the feedthroughs, during the shut-down of January 1986.

This should get rid of most of the slow variations with frequency present in the H signals and detectable as a background to the fast changes in the V signals. There remains the suspected resonant-type fast changes. During the August shut-down we also placed ex-ISR damping resistors in the bellows volume upstream of PU1 and in the flared end transition from PU chamber to circular beam pipe downstream (Fig.6). A clearing electrode consisting of one of the resistors mounted horizontally and transversely across the end transition was also installed, and checked carefully for leakage coupling to the outside. Since these resistors represented a much smaller percentage of the affected chamber volume than was found necessary in the ISR in order to drop the Q by a factor of 10, it is not surprising that if resonances are indeed our problem, nothing happened.

Our plan therefore for January 1986 is to fill as much as is possible of the PU1 environment with damping resistors, and to fit solid dielectric cables and Ceramaseal SMA feedthroughs. It is also planned to install the 4-8 GHz PU and kicker during the January shut-down, so attention will have to be given to possible local resonances and their damping in SS24 and also in SS13 near the kicker, since propagation and resonant behaviour is more likely where apertures measure many wavelengths.

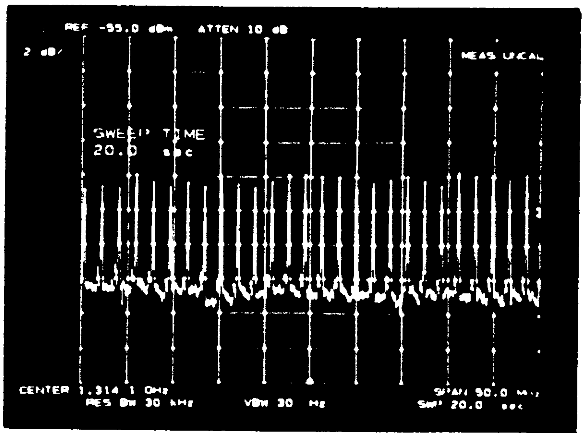
As a postscript to these notes it should be mentioned that the revolution harmonic amplitudes in the FNAL Debuncher system were satisfactorily low over a wide band (Fig. 9 shows the mid-band performance in June 1985). This is encouraging also for ACOL, as it seems to suggest that there is an averaging-out of imperfections accompanying the large number of junctions in a combiner board.

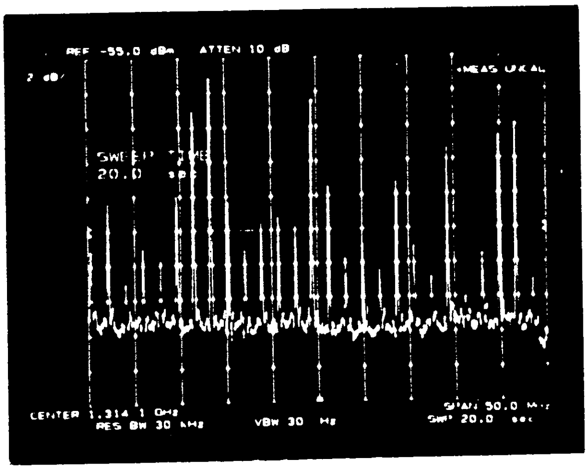




H Schottky V Schottky

Fig. 1 PU 1 17.3.83

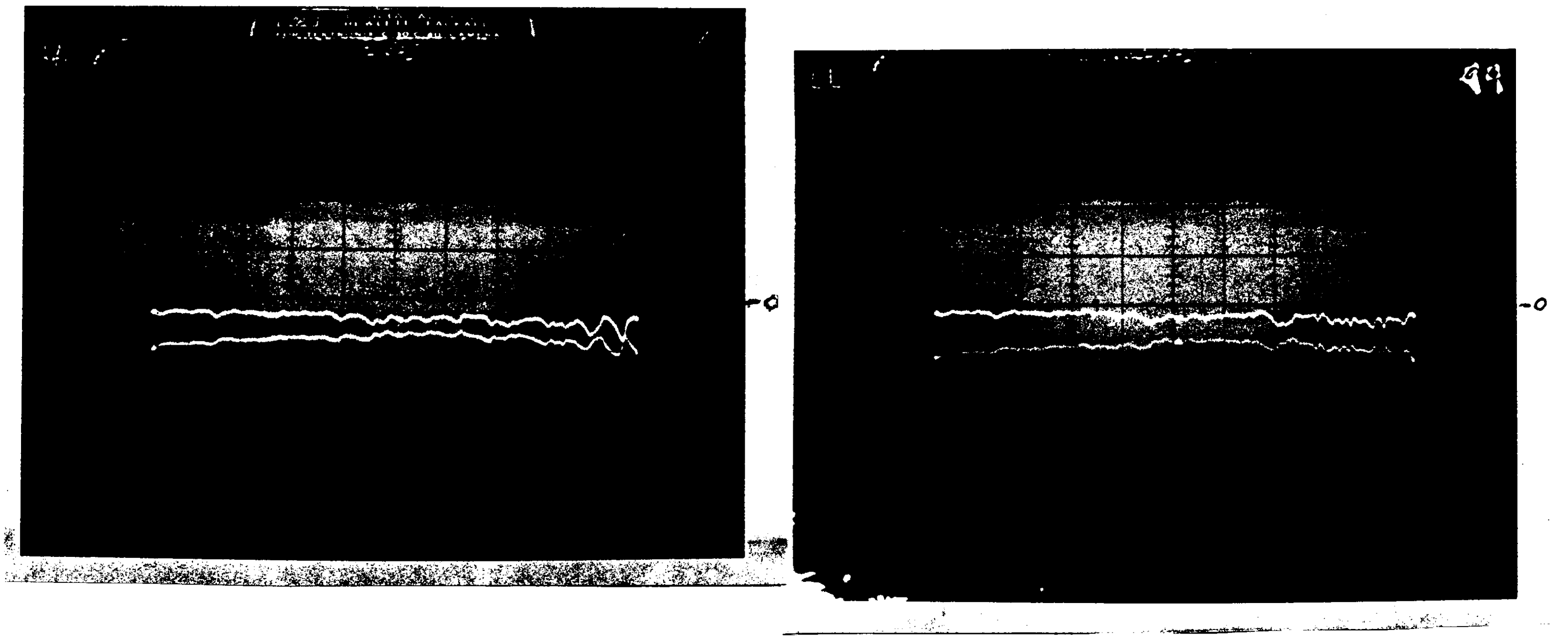




H Schottky V Schottky

Fig. 2 PU 1 19.5.83

Fig. 3 Layout of Pick-up circuit



Upper slot line Lower slot line

Top traces - amplitude 10 db/div.

Bottom - Phase 90 deg./div

Fig. 4 Transmission through Pick-up slot line.

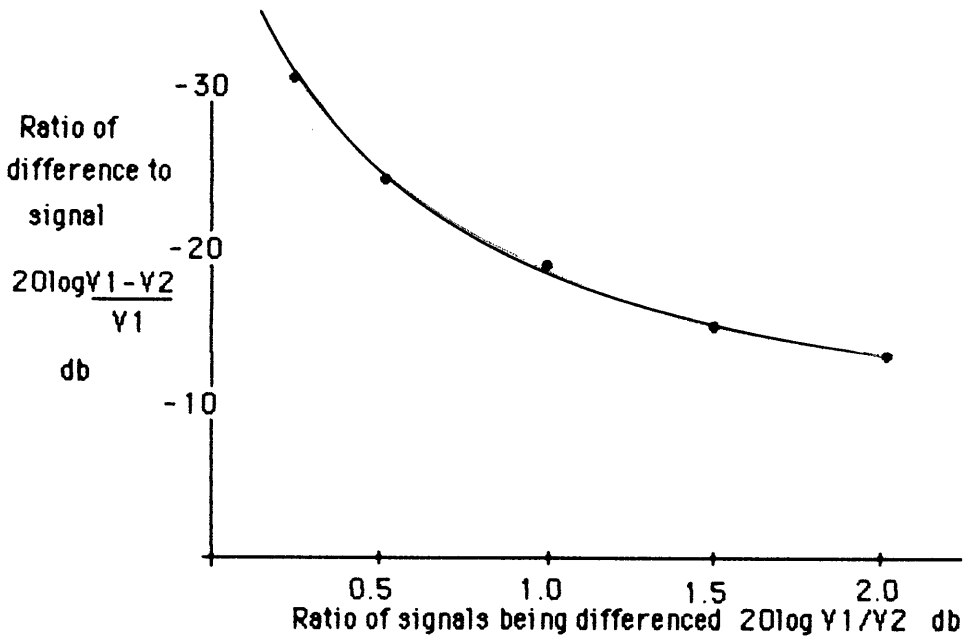


Fig. 5 Dependence of rejection on out-of-balance

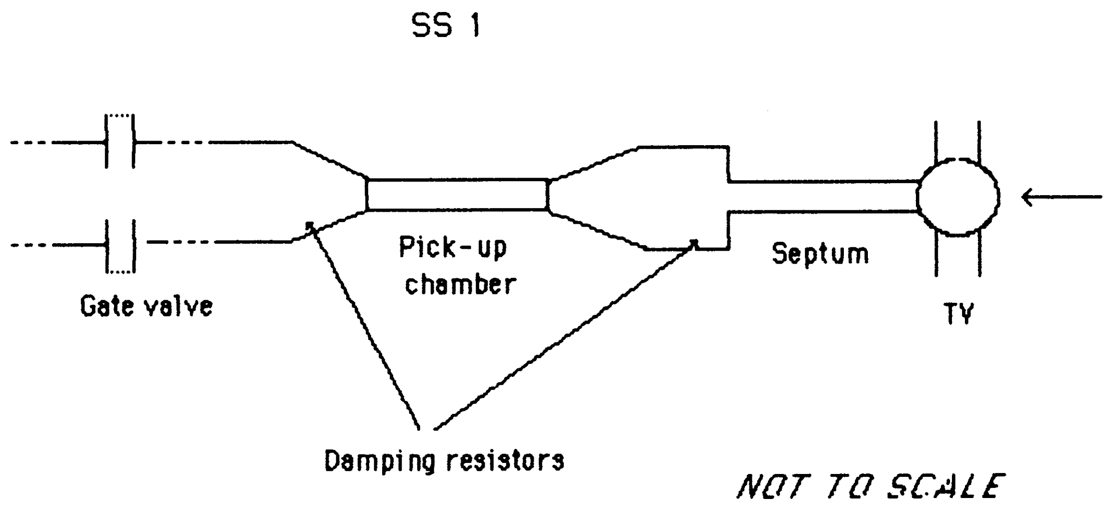


Fig. 6 Machine layout in vicinity of PU 1

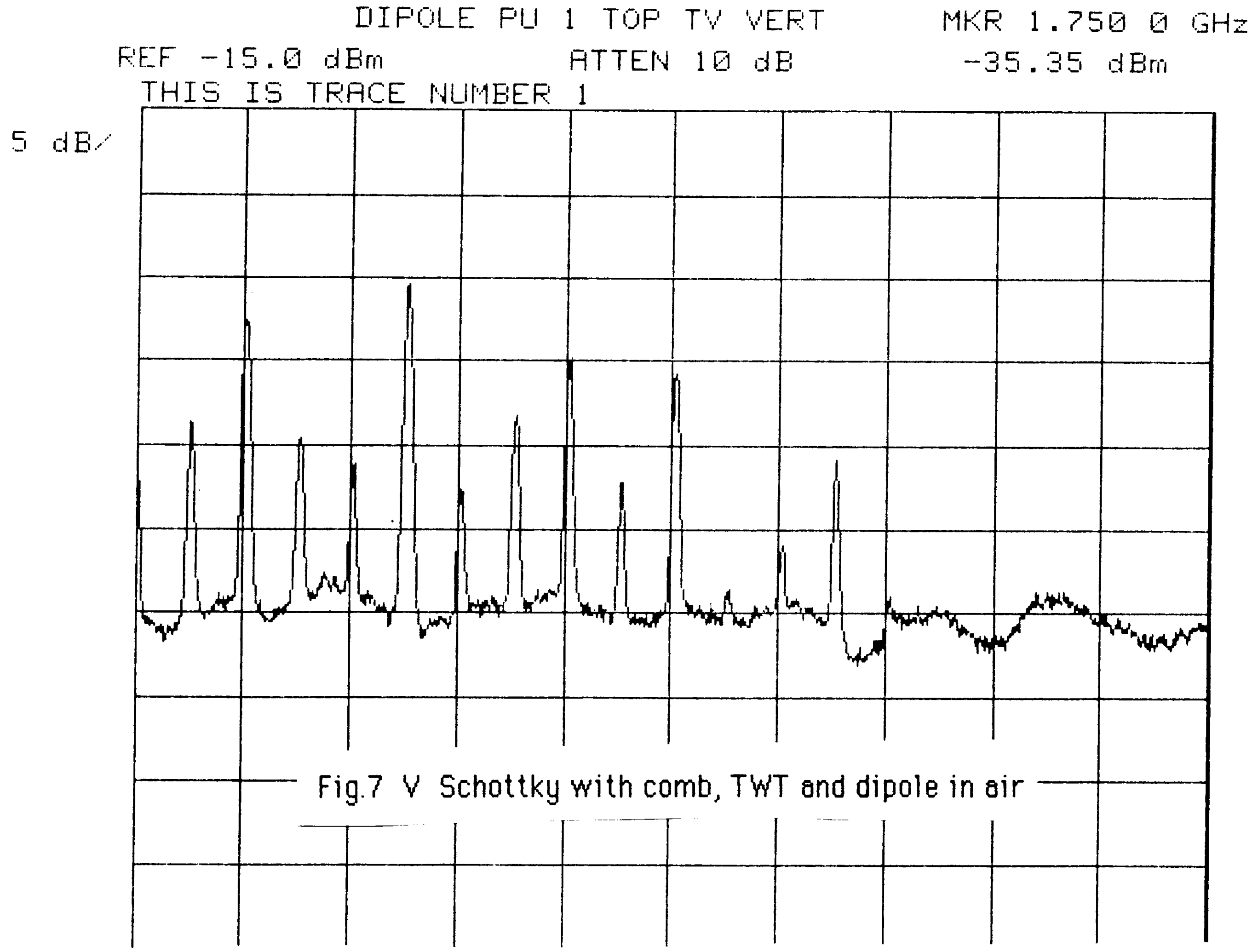


Fig.7 V Schottky with comb, TWT and dipole in air

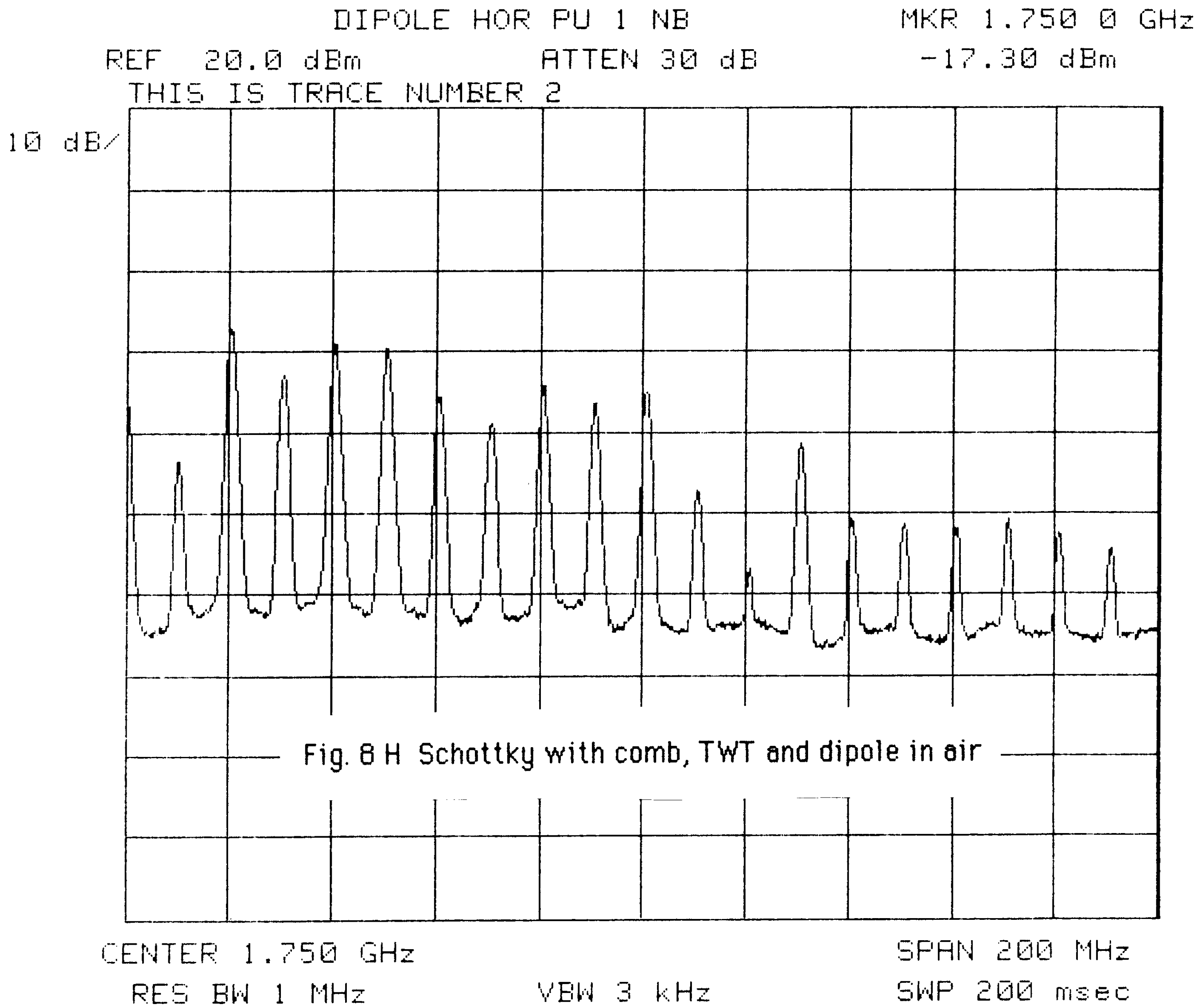
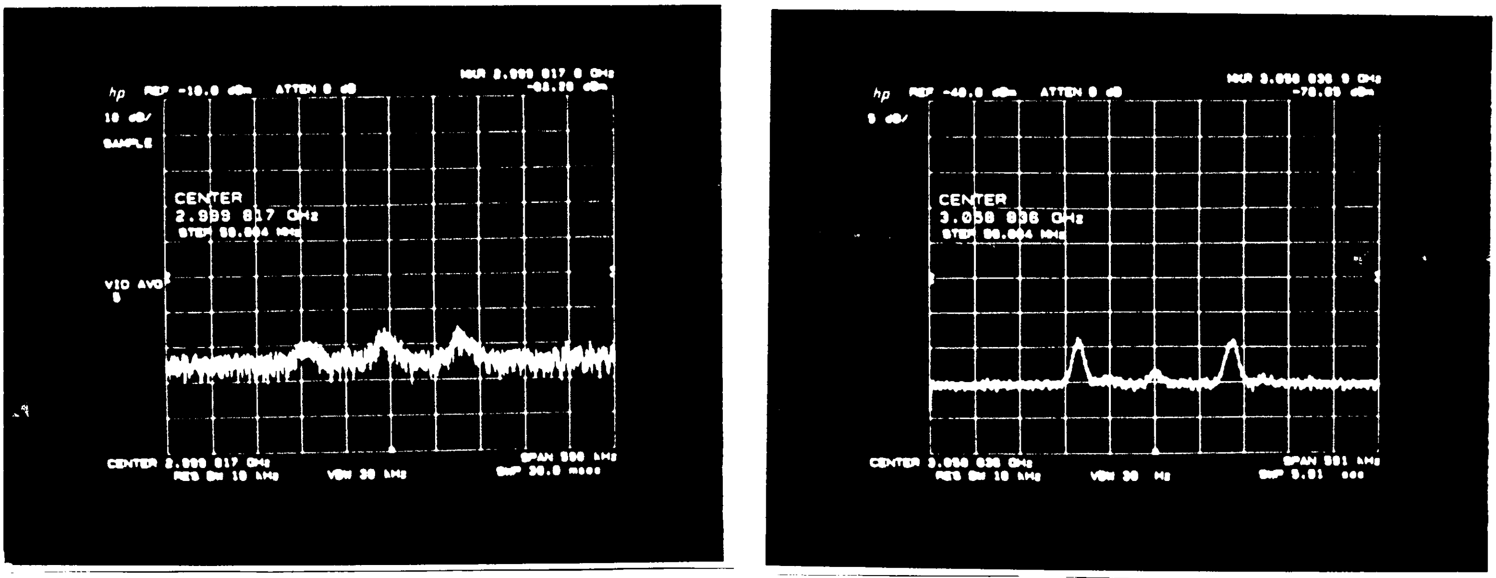


Fig. 8 H Schottky with comb, TWT and dipole in air



Before orbit bumps After orbit bumps

Fig 9 FNAL Schottky signals, Debuncher 8-9 June 1985.