National Radio Astronomy Observatory
949 N. Cherry Avenue, Campus Bldg. 65
Tucson, Arizona, 85721-0655 USA

Tel: 520-882-8250 Ext. 158 **FAX: 520-882-7955**
E-mail: wgrammer@nrao.edu

Date: 18 November 2002

To: Antonio Perfetto, NRAO

cc: Charles Cunningham, HIA
Anthony Kerr, NRAO
John Payne, NRAO
Edward Wollack, NASA

From: Wes Grammer, NRAO

Subj: NASA/GSFC Trip Report, 7-9 November 2002

The purpose of this trip was to characterize four prototype orthomode transducers (OMTs), as part of the OMT development effort for the ALMA Band 6 Front End cartridge. The goal was to verify that an existing W-band OMT developed for ALMA Band 3 could be scaled for use in the Band 6 cartridge. Measurement was done with an Agilent 85106D vector network analyzer (VNA) equipped with Oleson WR3 millimeter-wave test set extensions, over a frequency range of 210-325 GHz. Testing was performed by myself and Dr. Edward Wollack, the designer of the OMT, at NASA Goddard Space Flight Center (Green Belt, MD).

A good part of the first day was spent getting NASA's VNA to work correctly with the Oleson WR3 heads, provided by NRAO. The millimeter-wave controller used in their system (85105A-K10) was a different variant than the one directly compatible with our Oleson heads (85105A-H03). In order to make the system work correctly, external amplifiers were needed to boost the RF, LO and two IF signals into and out of each head, 8 in all for both heads. These had been obtained in advance by Dr. Wollack direct from Chuck Oleson, who very generously loaned them to us. We managed to scrounge the necessary power supplies and RF pads to get all signals up to the proper levels at the WR3 heads. A block diagram of the VNA setup is shown in Figure 1. Next, the VNA system configuration was modified to compensate for the extra doubler built in to the Oleson heads, which is normally not needed in the -K10 configuration. Finally, the Start and Stop frequencies were set to 210 and 325 GHz respectively, averaging enabled and the no. of averages set to 128, and a two-port TRL calibration with the WR3 performed. This was successful, and gave us around 40-45 dB available dynamic range for return loss measurements. More averaging would have been desired to lower the peak-to-peak noise in the thru response, but in the interest of time we deemed this initial calibration good enough to characterize the tapered transitions, which were the first parts measured.

To get accurate measurements of the OMTs, well-matched transitions are needed between the

OMT output ports and the precision WR3 flanges used on the Oleson heads. Internally, these have a gradual linear taper in both planes, to adapt to the slightly larger waveguide dimensions (‘WR3.7', or 0.037" x 0.0185") used in the OMT. Figure 2 shows a drawing of this transition, from which three were fabricated. Measurements were made of different pairs of back-to-back transitions, and all were nearly the same: >22 dB return loss (combined) over 90% of the band, and 0.6-0.7 dB insertion loss in each transition. Figure 3 shows data taken from one set. The instability at the upper end of the band may indicate mode conversion in the larger end of the waveguide, which has a single-mode upper cutoff limit of ~319 GHz. Also, it was noted that with the mating flanges rotated 180 degrees, the insertion and return loss performance had a small but steadily increasing degradation above 275 GHz, indicating that the centerline of the waveguide is slightly offset from the flange center on one or both flanges at the reference plane. Nevertheless, the performance is still quite good.

The small mismatch and insertion loss of these tapers can be removed from the OMT measurements by recalibrating the system at the outputs of the tapers. This was successfully done using a TRL calibration, with two line standards (0.0398" and 0.0557" thick) and a waveguide short (reflect standard). The WR3 calibration kit file from Oleson was modified for these line lengths and upper and lower cutoff frequencies of WR3.7 guide. The averaging on this cal was increased to 512, and the number of points to 401, to reduce the noise and improve resolution. We could have used even more averaging, but the time for each sweep got so slow we were concerned about the time it would take to get all our measurements in, so we compromised. The frequency span was adjusted to cover 200-315 GHz, within the single-mode range of WR3.7 guide. It turned out that the Oleson units positively did not work any lower than their specified limit of 210 GHz, as we found after calibration, so this portion of the data can be ignored.

A complete measurement set was obtained from one of the OMTs made by J&E Precision (s/n 3), shown in Figures 4-8. This includes main arm and side arm insertion loss and return loss, and main arm to side arm isolation. The insertion loss is approximately half of the value of |S11| shown, with the ripple in the response likely due to the finite directivity of the coupler in the VNA test set. In the side arm, the loss is around 0.3 dB over most of the band, with a dip down at ~0.5 dB near 285 GHz, and a sharp roll-off above 305 GHz. The main arm has overall a slightly higher loss, ranging from 0.35 to 0.6 dB, with a similar dip[1] as in the sidearm. The higher loss is not surprising, because J&E used EDM (Electric Discharge Machining) to cut the main arm channel in the top half of the block, which often gives a rougher finish, with greater associated RF loss. The measured return loss for the main arm is good: >20 dB over the entire band, and 22-25 dB over 95% of the band. The actual return loss is probably even higher, because the common port termination consisted of three cascaded waveguide sections, which likely contributed as much or more mismatch to the overall response as the OMT itself. We would need to fabricated a higher-quality square waveguide load to accurately measure the main arm return loss in the future. The side arm return loss is lower, ~15-17 dB over most of the band, with a pair of resonant dips at 223 and 305 GHz, which were as expected. Isolation is from 25-30 dB over the entire band, with a reasonably well-matched termination on the common port (the data in the plot includes the ~4 dB loss in the transitions).

[1]Subsequent measurements seem to indicate the culprit is a small gap at the mating waveguide flange, caused by slight misalignment of the block halves. This does not appear to be a fabrication error, but rather an assembly problem. The second J&E unit (s/n 1) exhibited very high sensitivity to flange torque, and had a bigger block offset.

The other three OMTs were measured, but because of calibration drift the data is not as accurate, and will not be included in this summary. When the new VNA system arrives, these units will be remeasured with a fresh calibration. However, qualitatively the results for all four OMTs were pretty much the same, indicating no serious problems with the design.

Figure 1 - Block Diagram of NASA WR3 VNA Test Setup

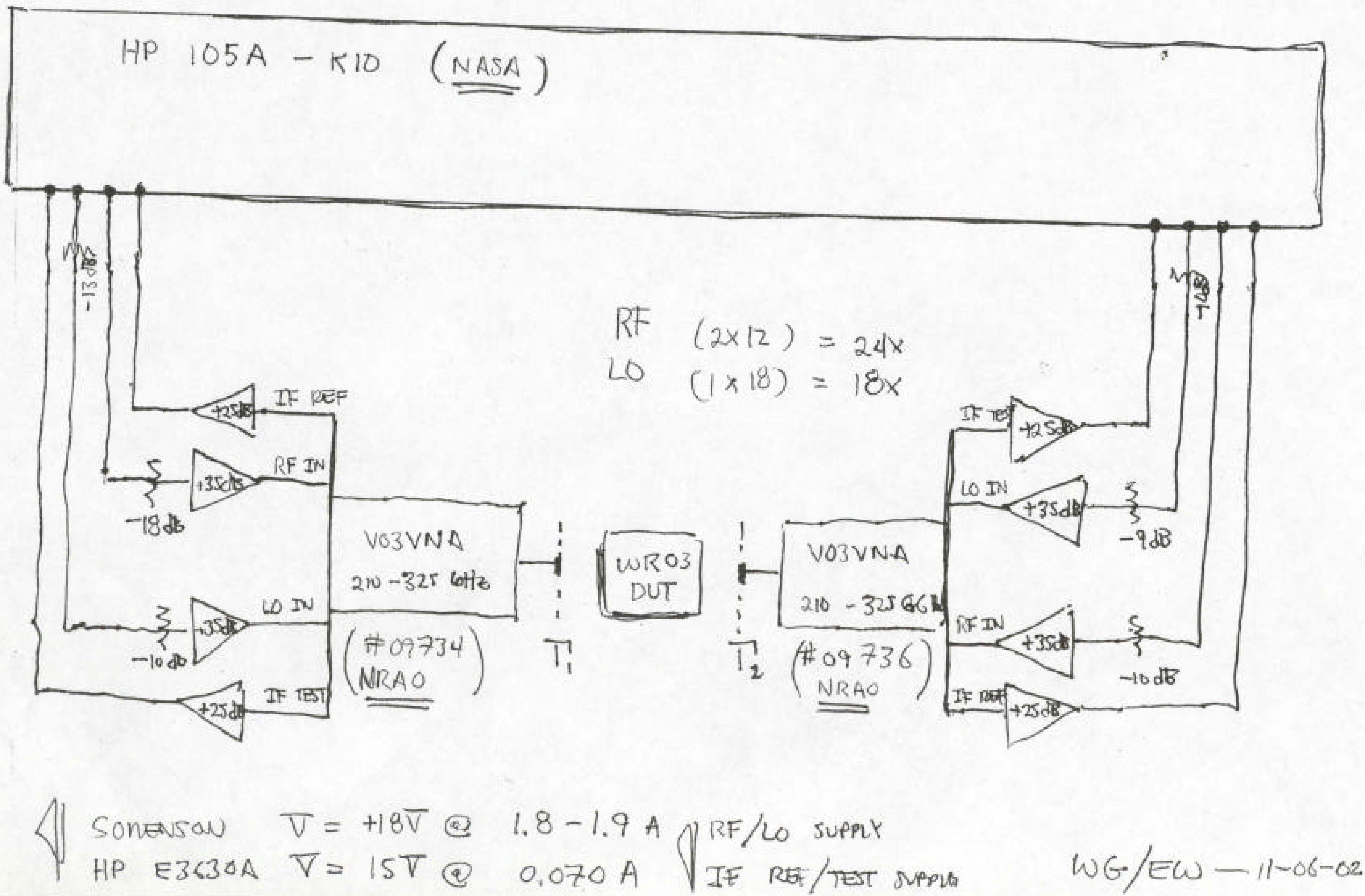

Figure 2 - WR3 to OMT Waveguide Taper Transition

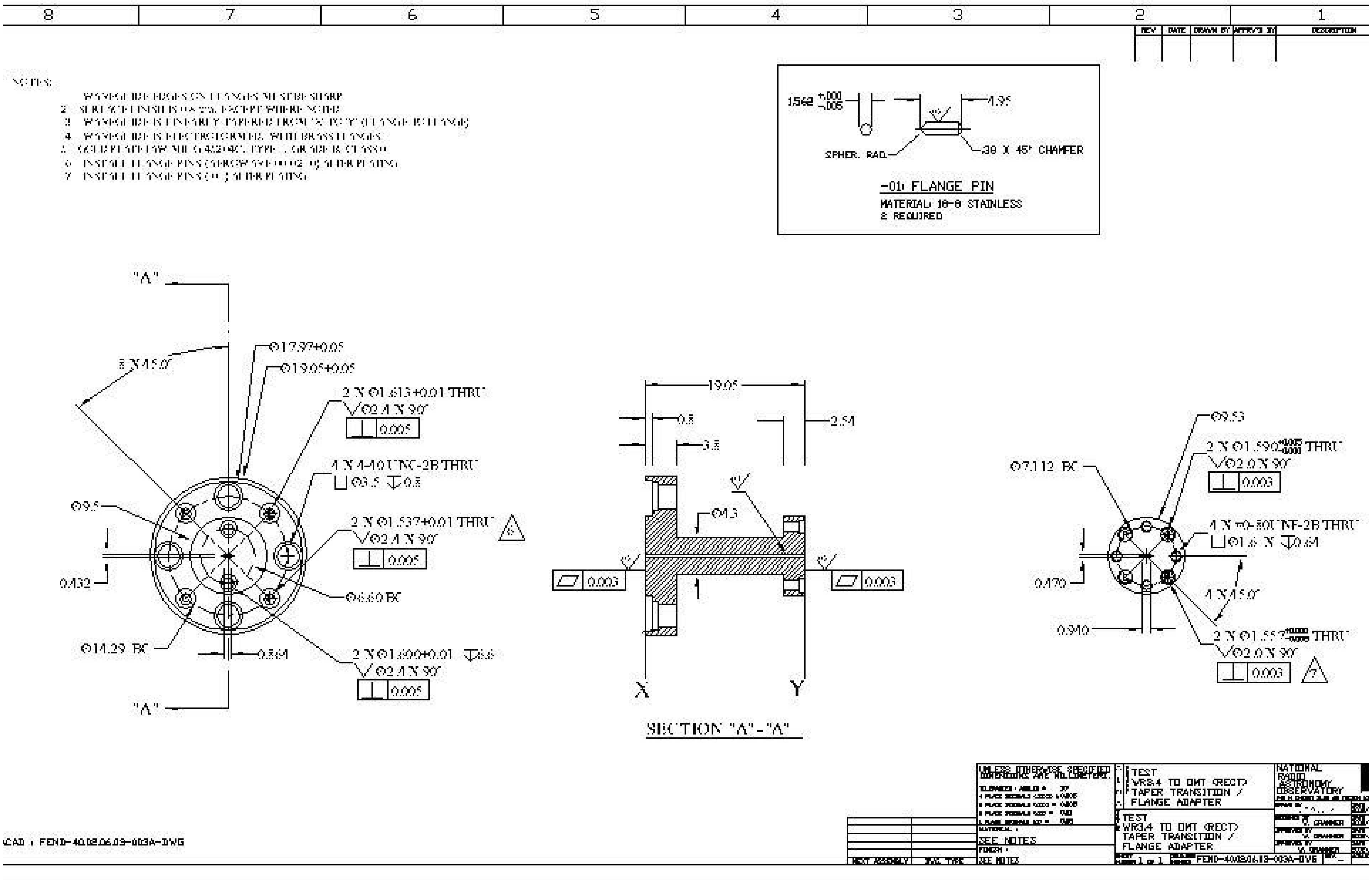

Figure 3 - Measured Data of Back-to-Back Taper Transitions

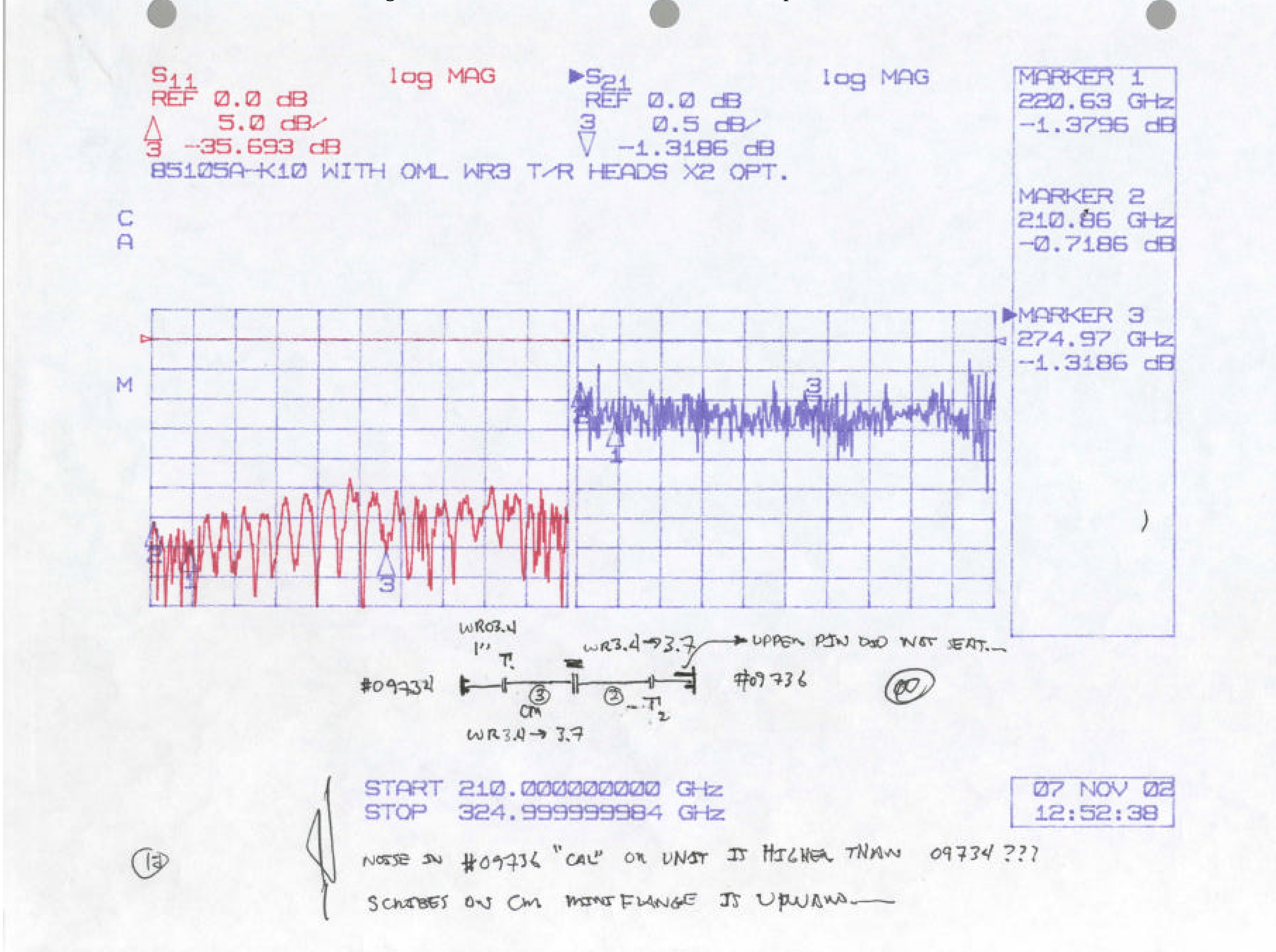

Figure 4 - OMT Side Arm Insertion Loss, J&E s/n 3

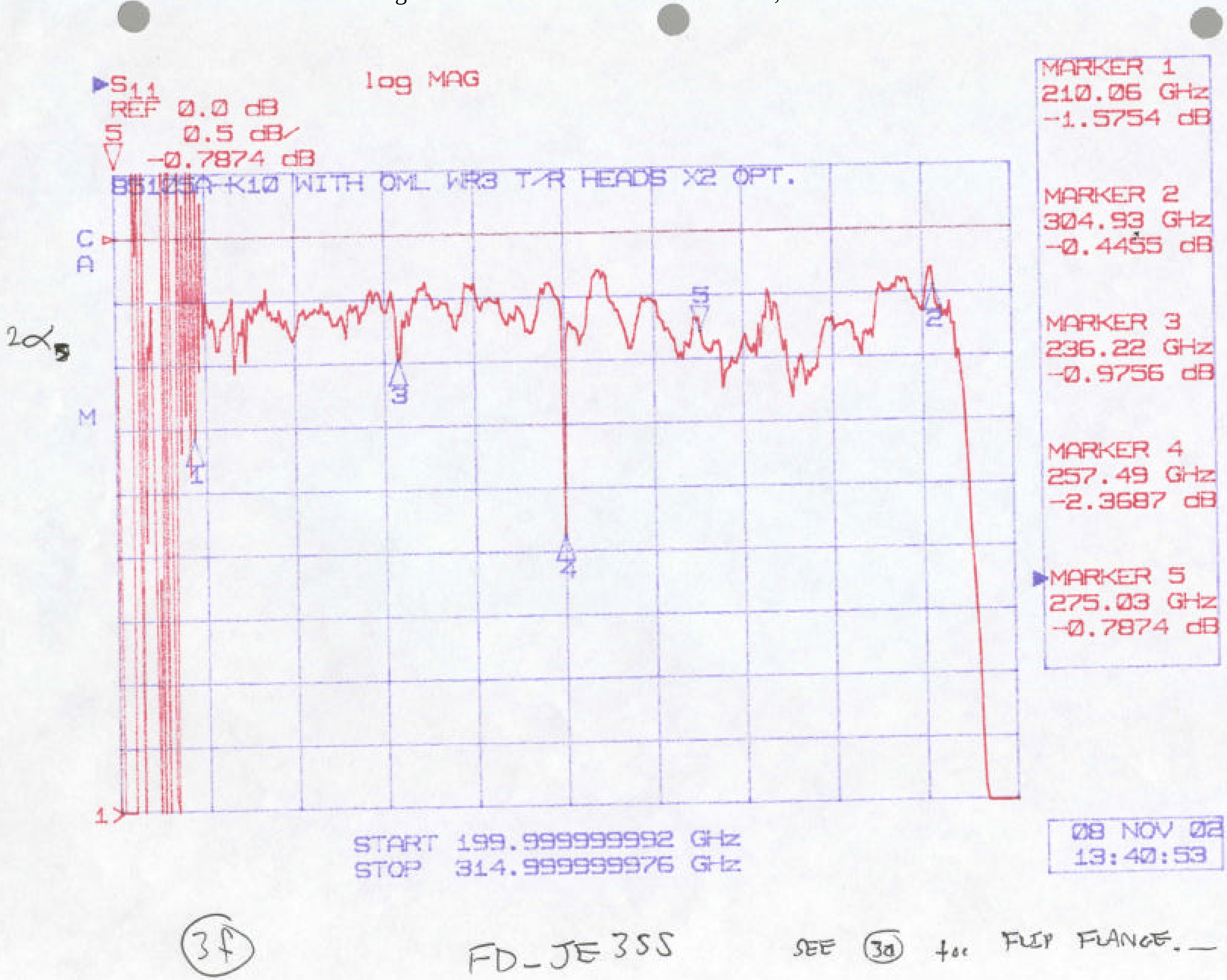

Figure 5 - OMT Main Arm Insertion Loss, J&E s/n 3

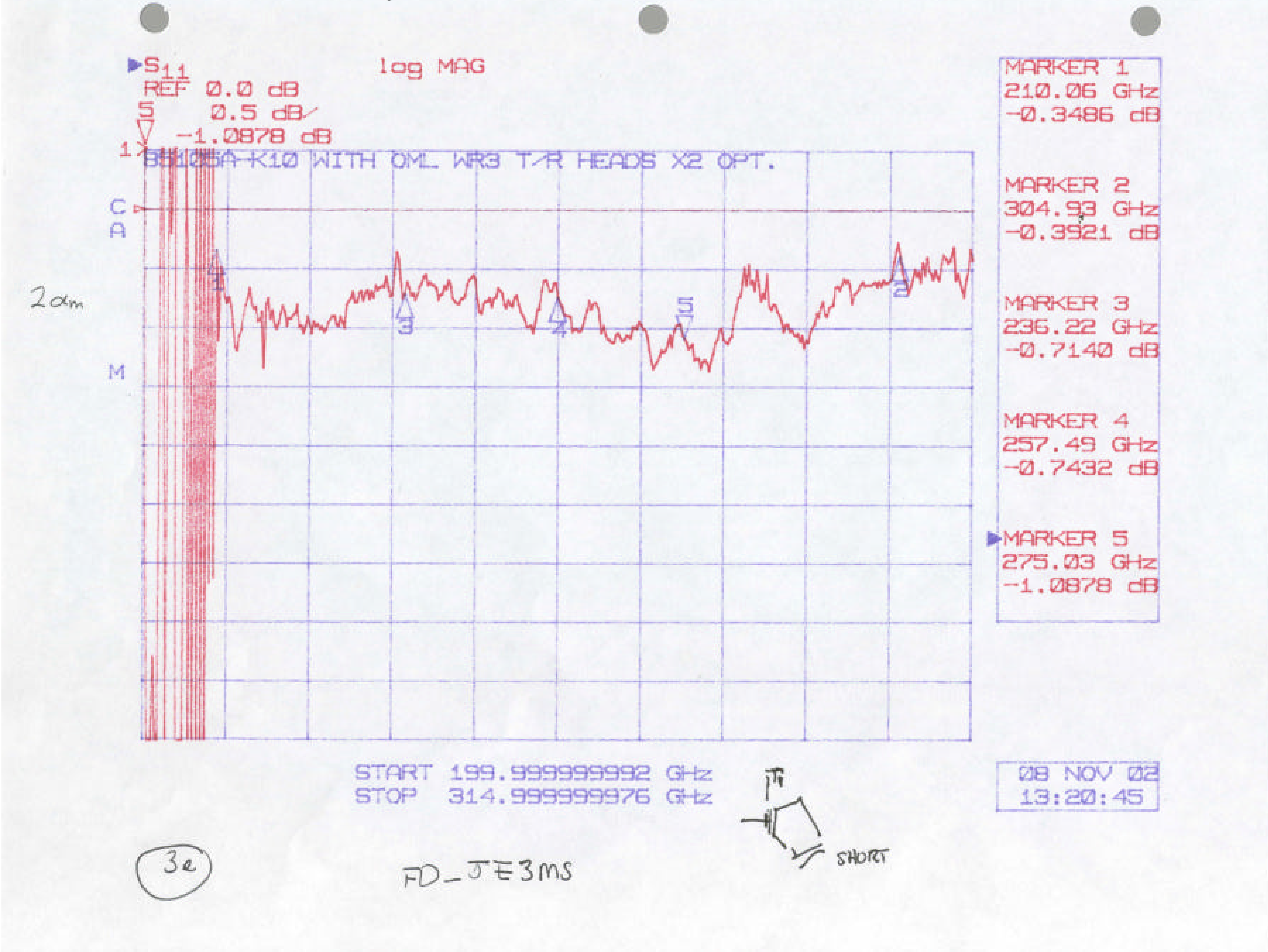

Figure 6 - OMT Main Arm Return Loss, J&E s/n 3

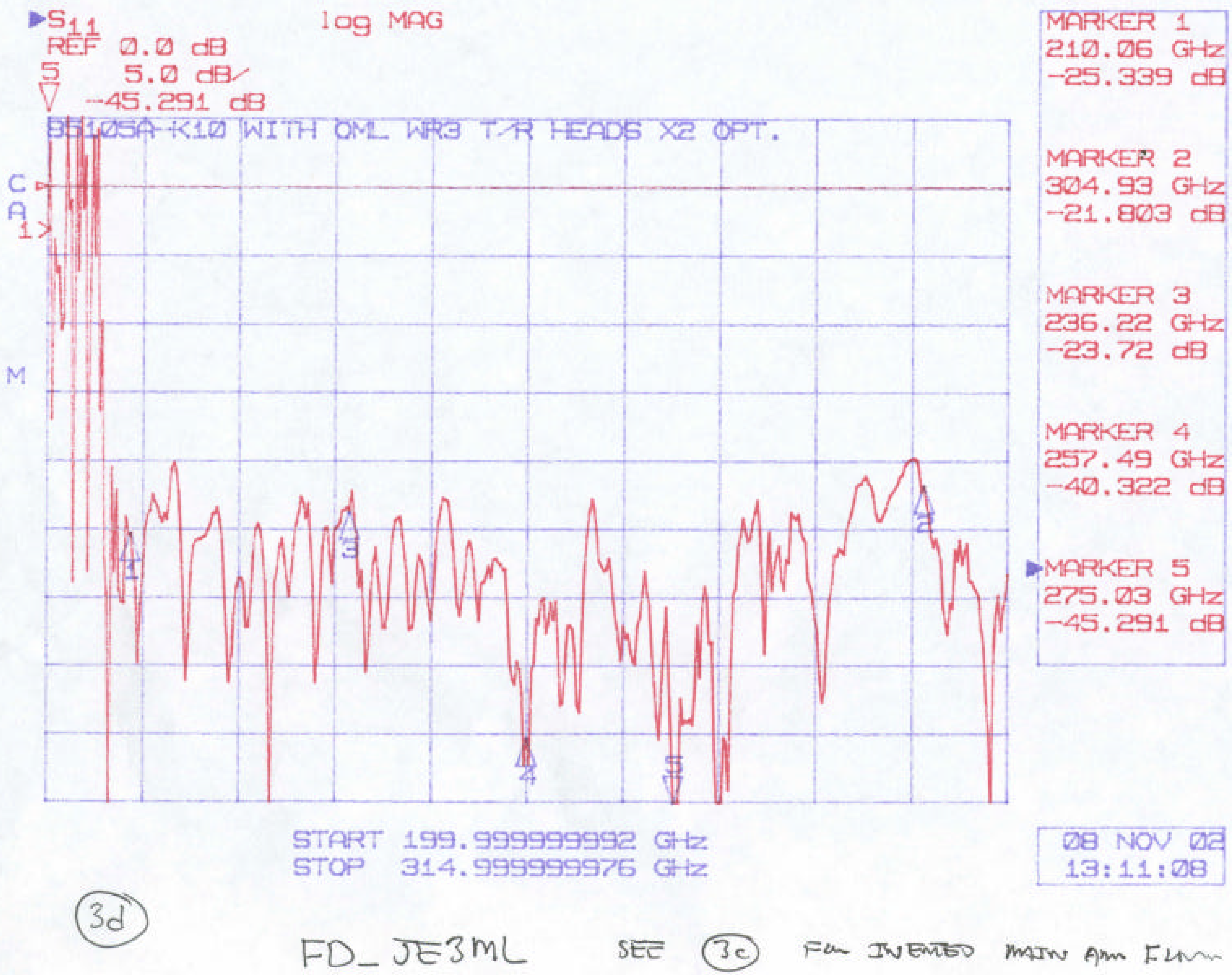

Figure 7 - OMT Side Arm Return Loss, J&E s/n 3

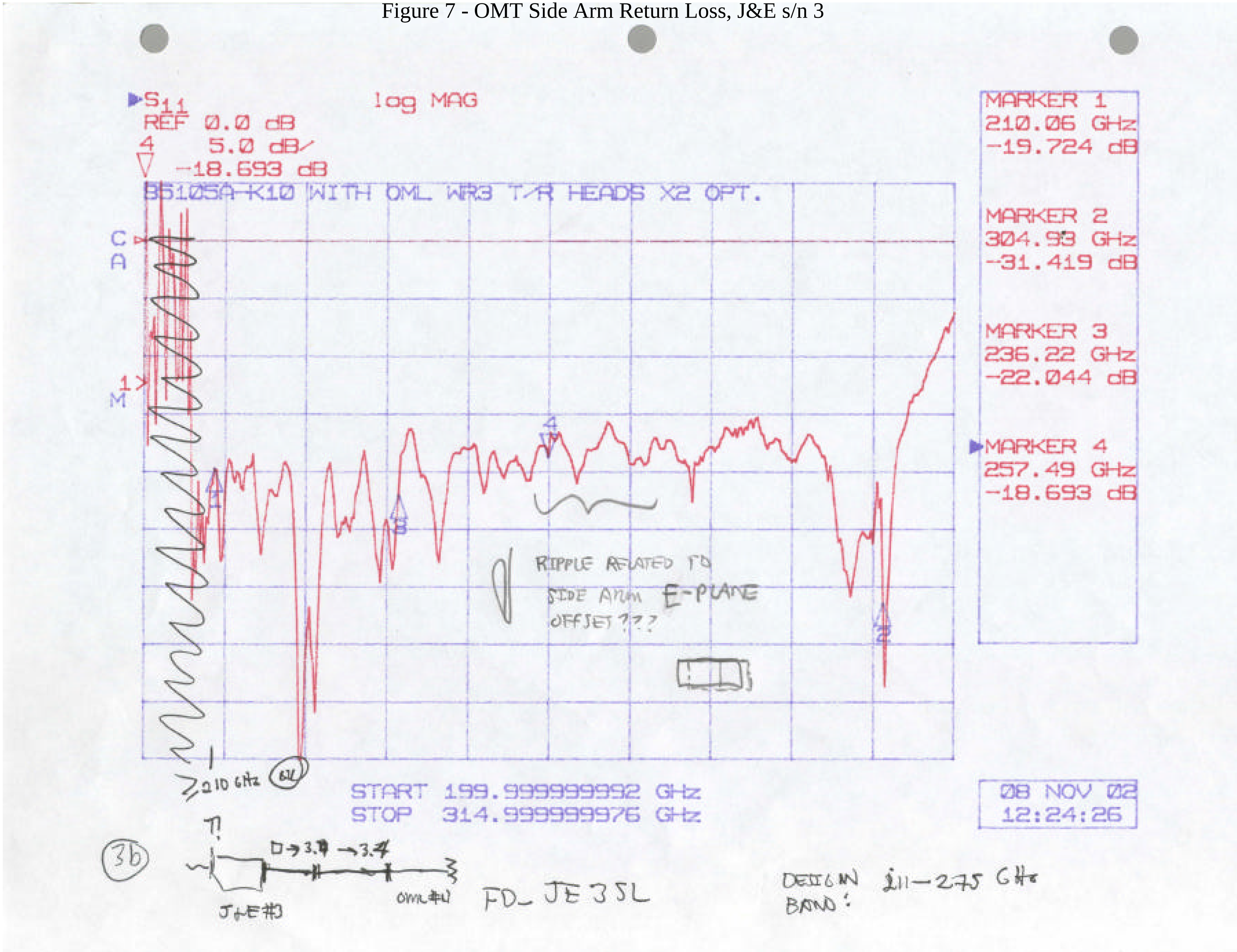

Figure 8 - OMT Main-to-Side Arm Isolation, J&E s/n 3