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PROCESSING, FABRICATION, AND DEMONSTRATION OF HTS INTEGRATED MICROWAVE CIRCUITS

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Cryoelectronics

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R&D STATUS REPORT

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Short Title of Work: Processing, Fabrication, and Demonstration of HTS

Integrated Microwave Circuits

Reporting Period: 10/25/94 to 1/24/95

DESCRIPTION OF PROGRESS

TASK 1.0: COMPARATIVE TECHNOLOGY ASSESSMENT

This task is essentially complete, but we are continuing to monitor progress in other technologies as they relate to the goals of this program.

TASK 2.1: INTEGRATED SUBSYSTEM SPECIFICATIONS

No work on this task was performed during this reporting period

TASK 2.2: FUNCTIONAL COMPONENT AND SUBSYSTEM DESIGN, FABRICATION AND TESTING

Improvements in the design of the coaxial-to-microstrip transitions for the microwave packages used in this task are being implemented. Preliminary tests have shown that improved return losses are obtained by shortening the pin of the SMA coax connector in order to allow bonding of the Au ribbon directly to the end of the stub allowing the ribbon to lie in the plane of the HTS films. In this reporting period, we have designed a "trough" connection which will further improve the electrical matching characteristics. The design uses a trough region for the full pin to lie in between the coax and microstrip. Sketches of the trough transition are shown in Figures 1(a) and 1(b), and a dimensioned drawing of that being fabricated is shown in Figure 2. Experimental results on this design will be obtained next quarter.

Improvements in network analyzer calibration techniques have been required in order to increase the reliability and accuracy of our measurements as device performance improves. The improvements include a more rigid cabling structure going into the test dewars and the use of Adapter Removal techniques that account for errors when calibrating for non-insertable devices (e.g. devices that have two female connectors, as ours do, instead of a male and a female).

In this reporting period we have established the use of Ditac in our substrate mounting technique, mainly for microstrip. Test results show good, repeatable

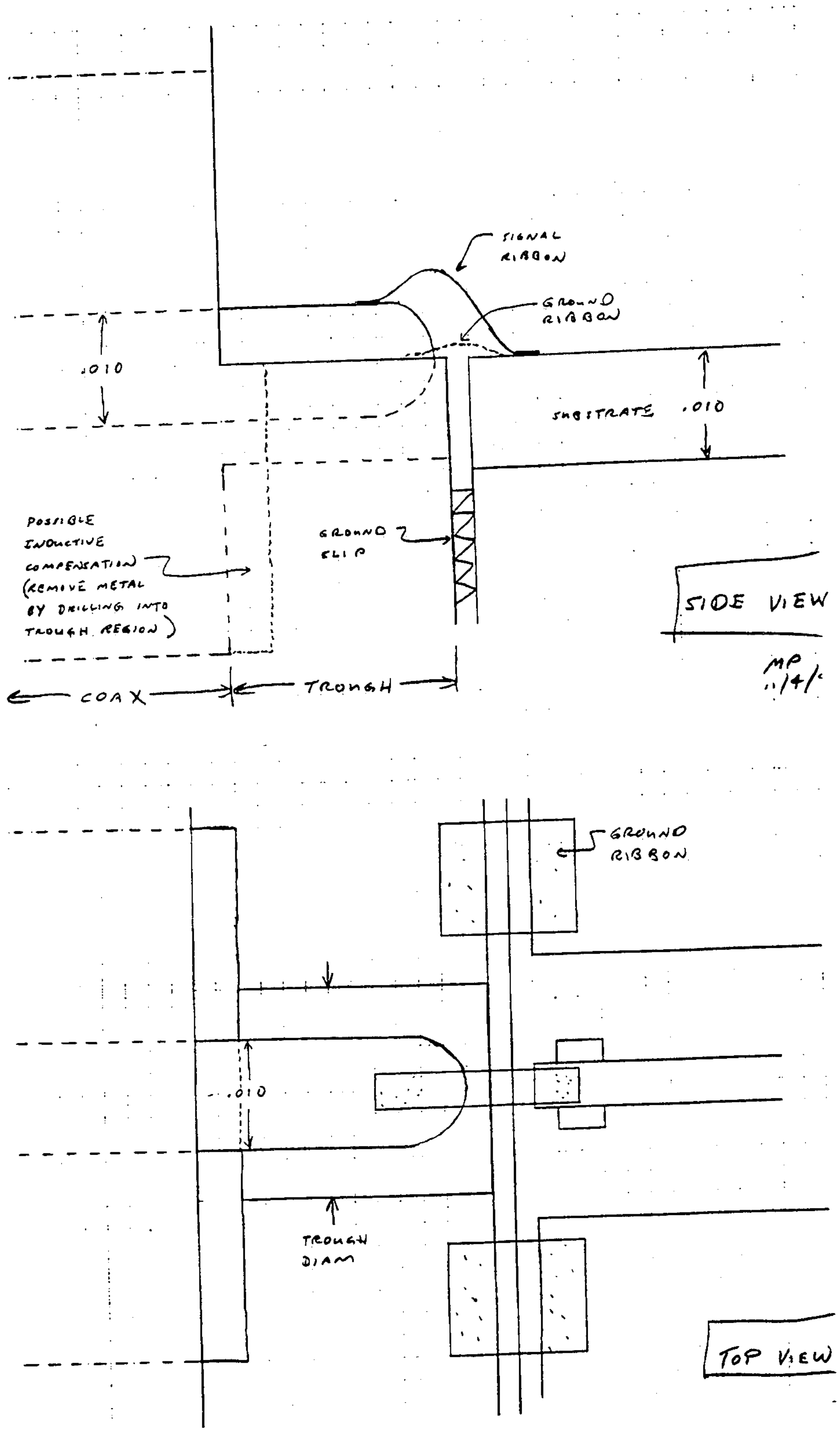


Figure 1 - Side (a) and top (b) schematic views of the trough coaxial-to-microstrip transition.

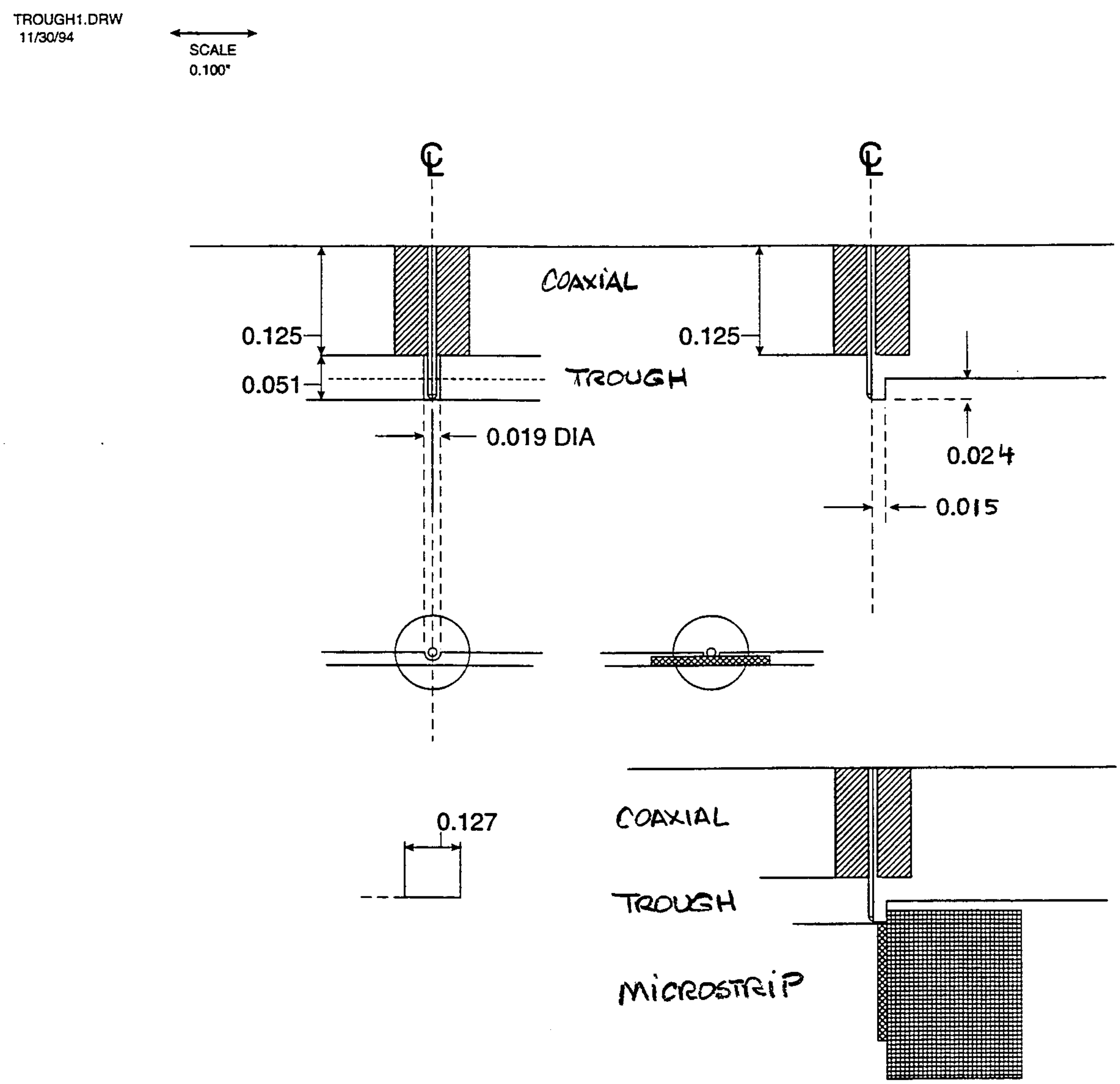


Figure 2 - Exact dimensions of the trough transition being fabricated.

measurements using this material, which has the added advantage that the substrates can be dismounted easily from the substrates.

Filterbanks

7-Pole Single Filters

Work on single 7-pole filters continued during this reporting period, with efforts to suppress the unwanted spurious mode interfering with the lower skirt of the filter (see Figure 2 of the previous Quarterly report, # 13). To explore the possibility that the unwanted mode is a surface mode in the substrate, a substrate which originally had two parallel filters printed on it was cut to a narrower size leaving just one filter in the middle. It was then tested in the same package, giving essentially the same result as before it was cut. An insert to the package was made so the package cavity containing the filter was made electrically narrower. Figure 3(b) shows the response, which can be compared with the case of a wide package, shown in Figure 3(a).

The time domain response, which is very important in this type of filter for EW applications, was measured and compared with the simulated response on the ideal filter. The theoretical and measured impulse responses are shown in Figures 4(a) and 4(b), respectively.

7-Pole Channel

Results on a 7-pole channel, incorporating a tandem coupler discussed in our last report, were also obtained in this quarter. Figure 5 shows the response of the channel, which can be seen to be very similar to that of an individual filter. The spurious mode on the lower skirt, discussed above, appears because no attempt to suppress it in the channel was made as yet. This problem will be treated in the next quarter.

50Ω Microstrip Lines

We continued using 50 Ω lines as test vehicles to assess the quality of our transitions and ground contacts. Figure 6 shows a response between 2 and 12 GHz on a 1-dB-per-division scale plot. This is to be contrasted with the plot reported in our last report. An improvement from 2 dB to 1 dB was obtained in the ripple above 7 GHz by using Ditac to attach the substrate to the carrier. Improved calibration techniques and SMA connections described above will be implemented in the next quarter and are expected

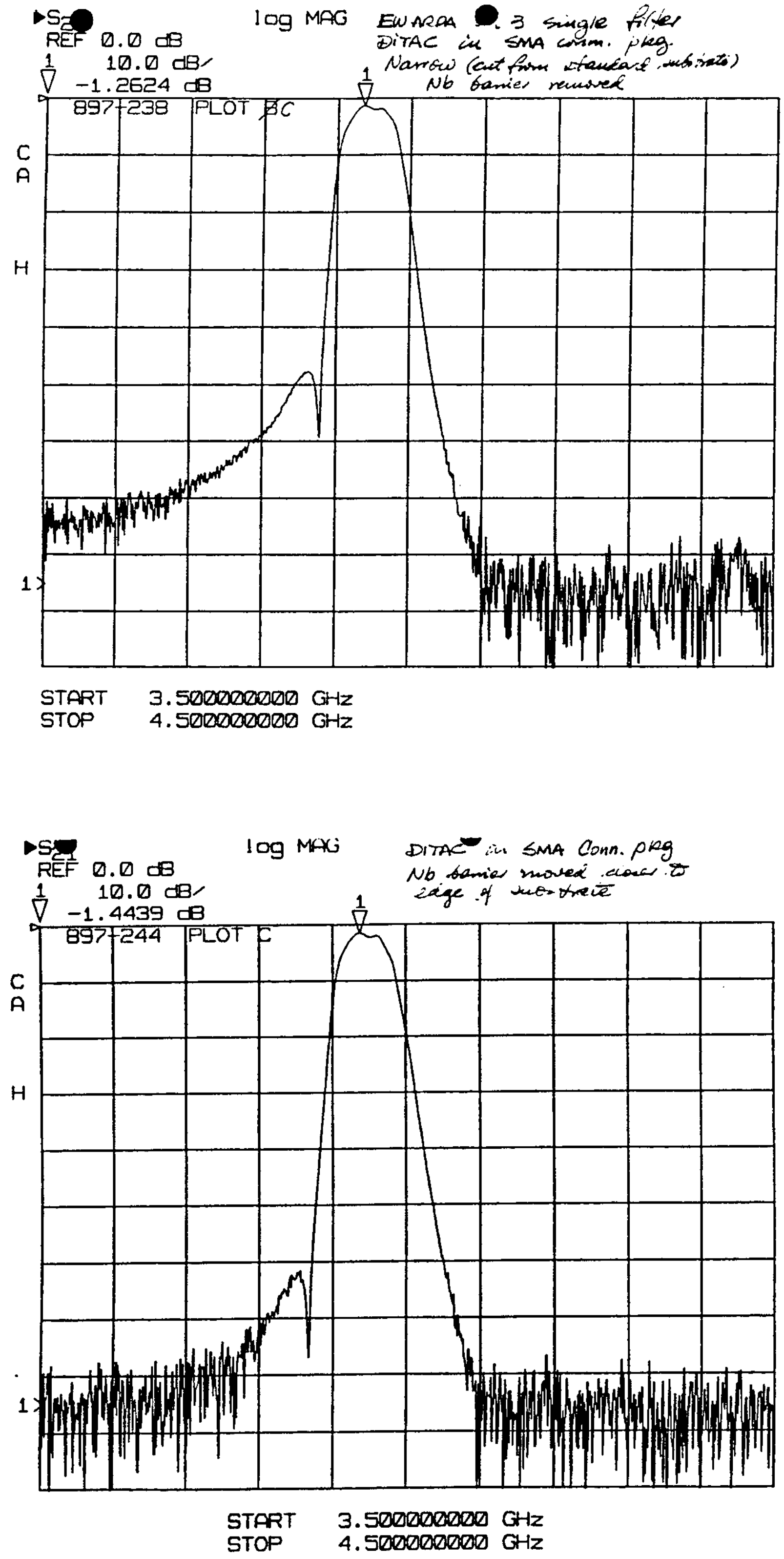
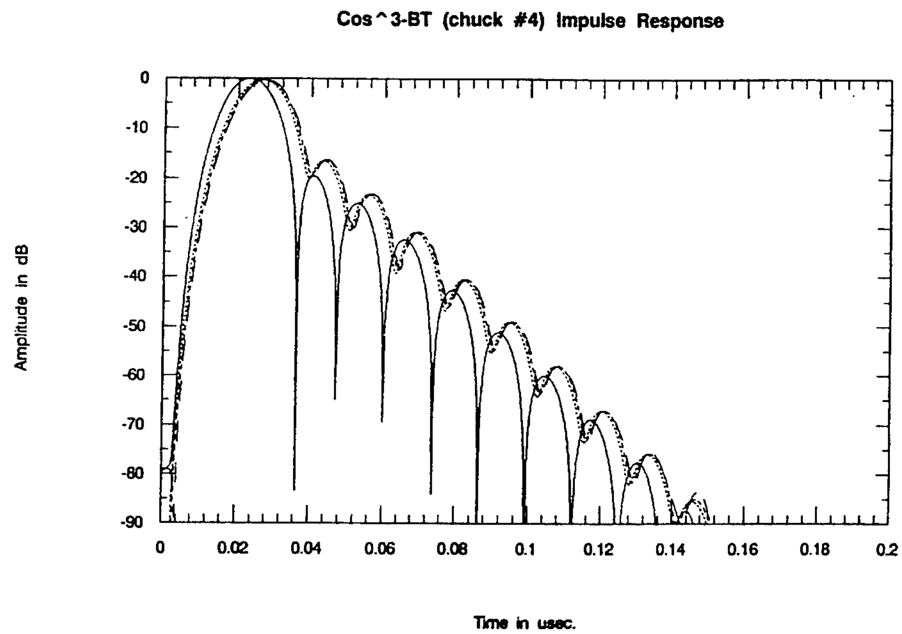


Figure 3 - 7-pole single filter responses when in the standard width (1.132") package (a), and in the narrowed down package (b). The package was narrowed down with an inset that made it 0.6" wide.



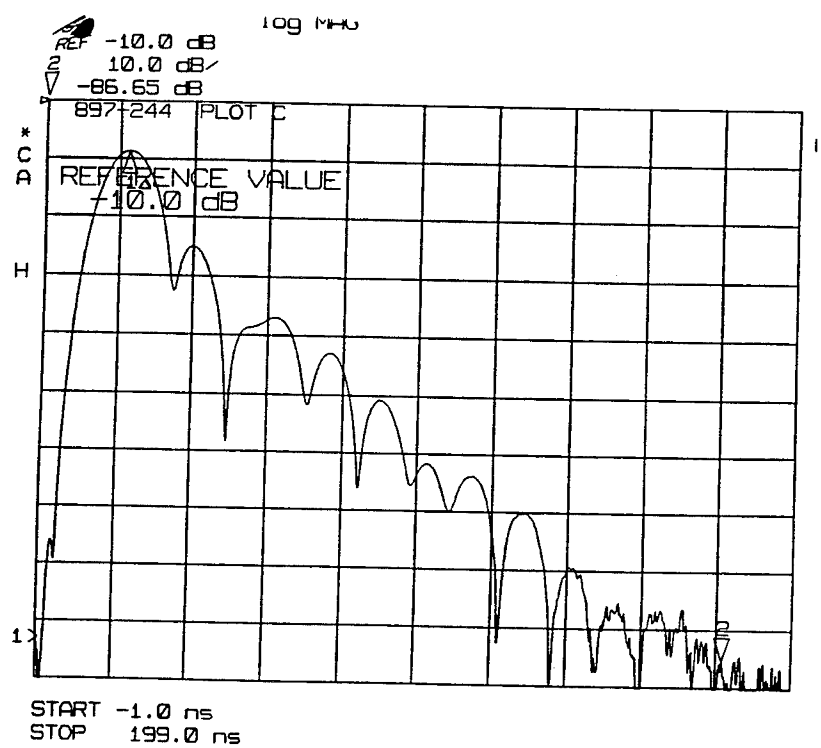


Figure 4 - Theoretical (a) and measured (b) impulse time-domain responses for the 7-pole filter.

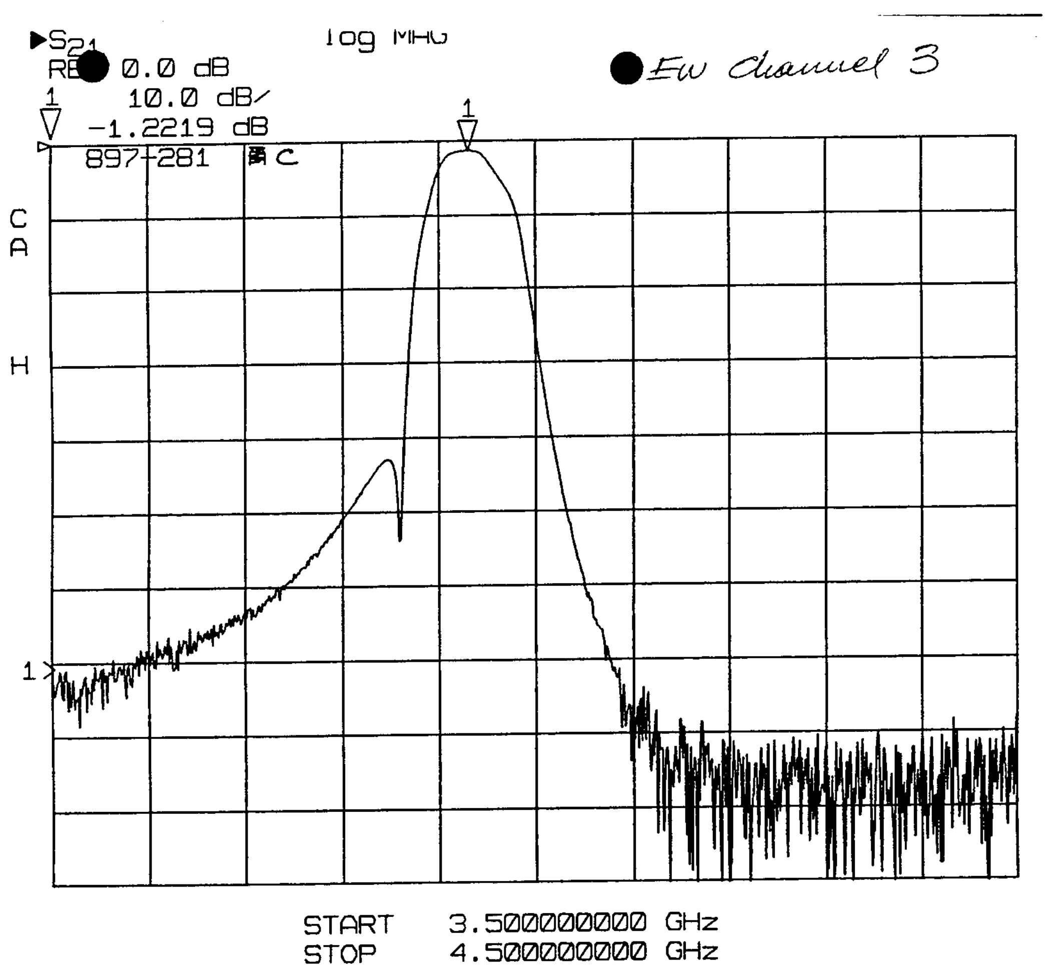


Figure 5 - 7-pole channel measured response. The channel comprises two sets of identical 7-pole filters and tandem couplers. The tandem couplers have gold wire crossovers.

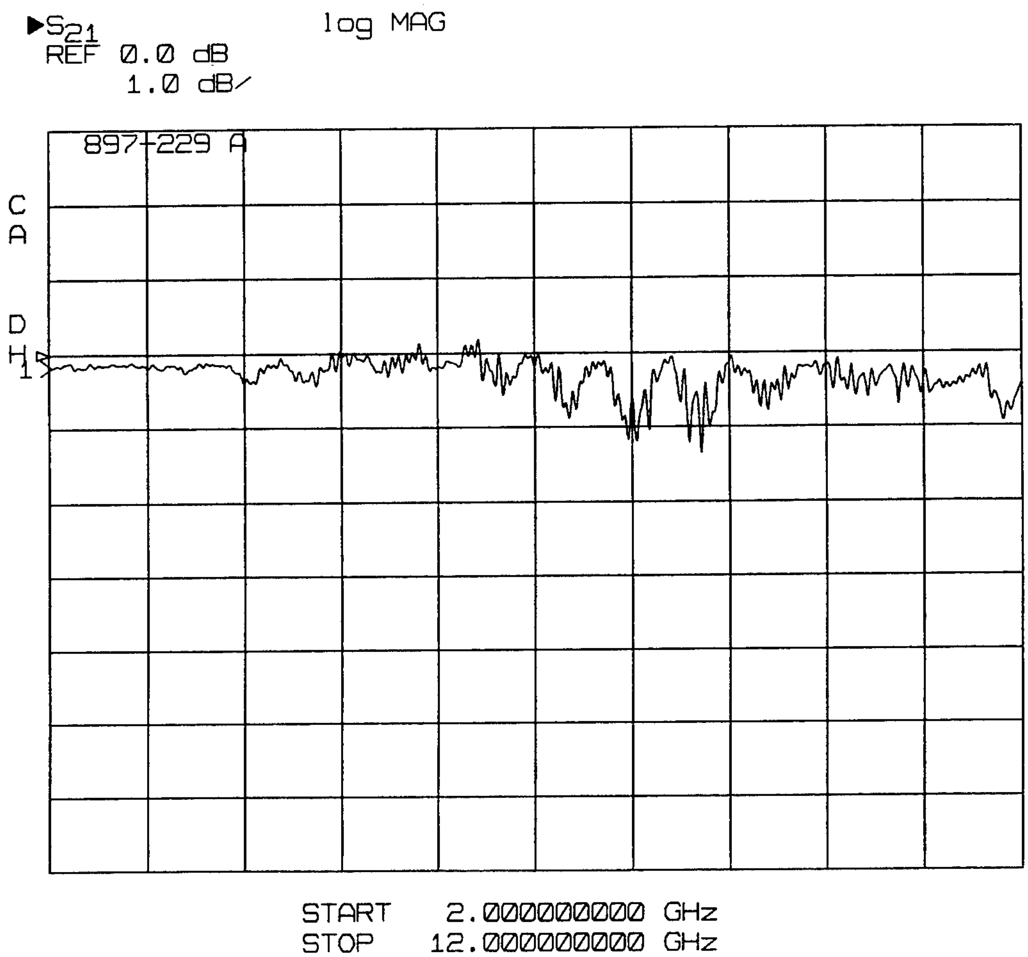


Figure 6 - Response of a 50-Ω microstrip line when the substrate is attached to the carrier using Ditac. This plot shows a significant improvement above 7 GHz over the results shown in our last report.

to produce further improvements in the return loss which is greater than 10 dB up to 6 GHz, but lower at higher frequencies.

Lumped Elements Filters

Q measurements of the lumped element test resonators described in our last report were made. The layout of the test wafer was shown in Figure 6 of our last Quarterly report. Each wafer includes three parallel L-C resonators in series with the coplanar input/output lines. Two of the resonators have interdigitated capacitors facing **Inward** and **Outward**, respectively, and one has a ceramic chip capacitor. Table I summarizes these results, which show the importance of the coplanar line crossovers (stitches) for phase equalization of the ground planes on both sides of the strip.

Table I - Q measurements on Lumped-Element Test Resonators

	Chip Capacitor		**Inward**		**Outward**	
Coplanar Stitch	NO	YES	NO	YES	NO	YES
Wafer W93-037	X	162	207	207	1059	1101
Wafer W94-052	609	2702	777	1319	977	1630

From these measurements it is clear that wafer W93-037 had a defective region. Nevertheless, very large Q's were obtained, despite the use of gold wire crossovers for the inductors. Q's of only a few hundred are realizable in conventional technology.

The design of a lumped element microstrip filter has been completed and will be fabricated and tested in the next quarter. The filter has a 5-pole, 0.01 dB ripple Chebychev response centered at 1.3 GHz with a 30 MHz bandwidth (2.3% relative bandwidth). Figure 7 shows the layout of the filter and its size relative to a 2-inch diameter wafer. Figures 8(a) and 8(b) show the designed response of the filter.

Delay Lines

Redesign of the input/output terminations of the delay line is almost complete. Revisions were made on the coaxial-to-coplanar transition (the trough connection

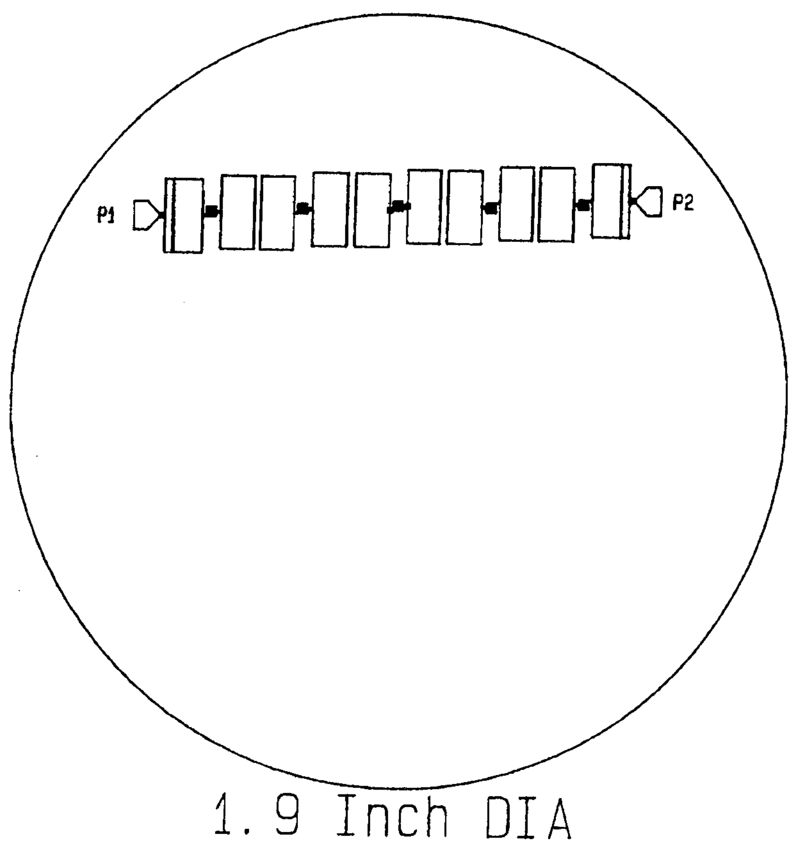


Figure 7 - Layout of the microstrip lumped-element filter designed, relative to a 2" diameter wafer.

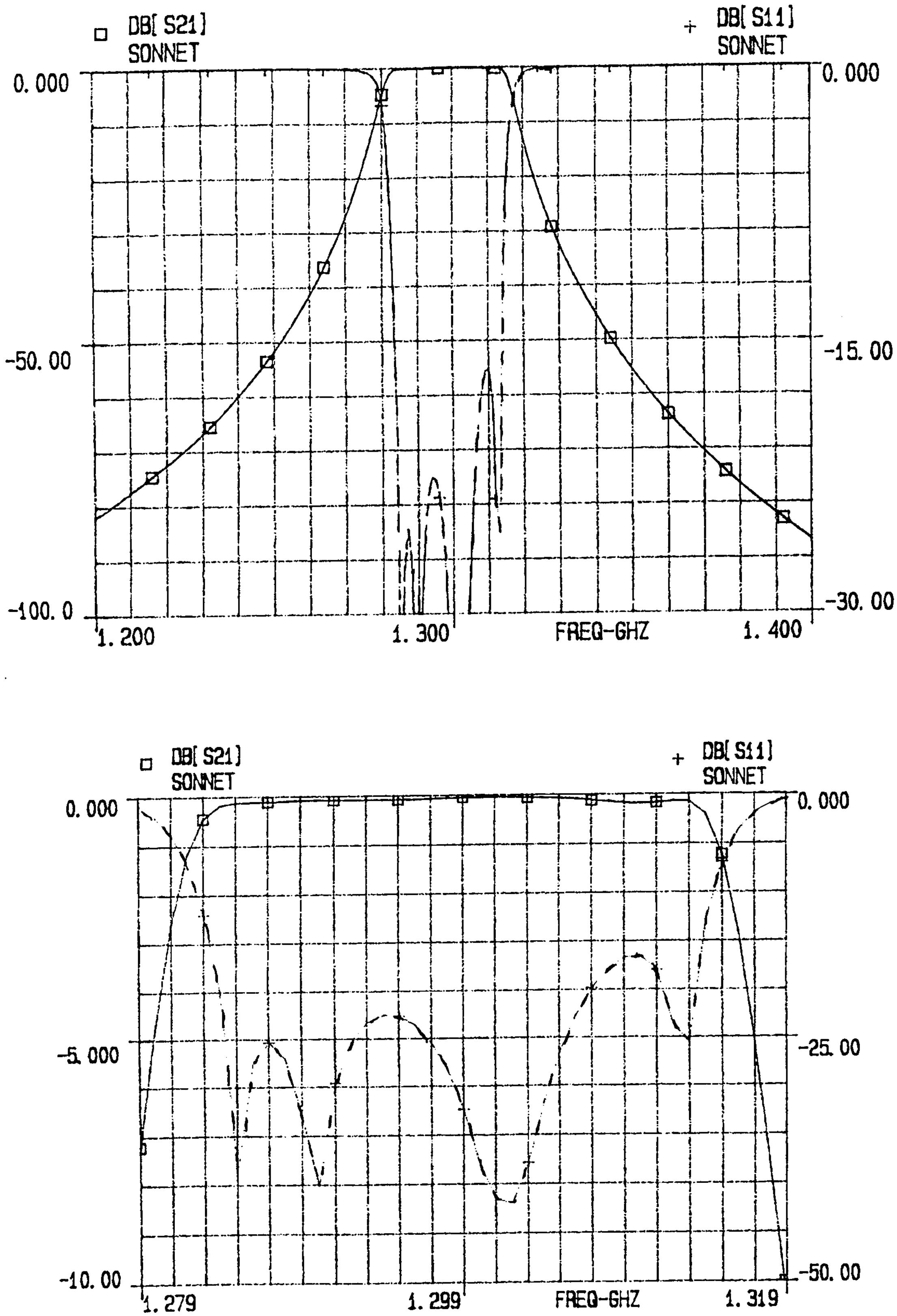


Figure 8 - Designed transmission and reflect responses for the microstrip lumped-element filter shown in (a) 200 MHz scale and (b) 40 MHz scale.

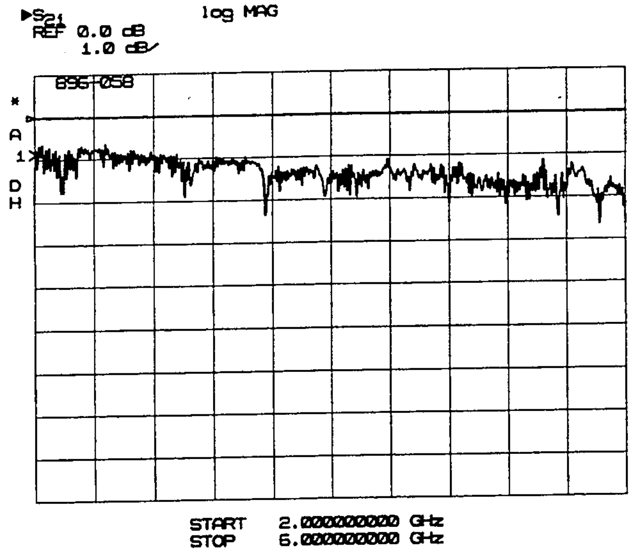
described above), the coplanar section of line and the coplanar-to-stripline transition. Following the preliminary results of the redesign and analysis, which showed that and increase in the size of the coplanar pads and a shorter electrical connection from the coaxial ground and the top stripline ground plane were needed, a delay line, made and measured earlier was modified with the addition of indium foil in the slots between the top ground plane and the coaxial connectors. Figure 9 shows the delay line reflection and transmission before the insertion of indium foil. Figure 10 shows the response when indium foil is added. Notice the significant improvement in return loss and the consequent reduction of amplitude ripple.

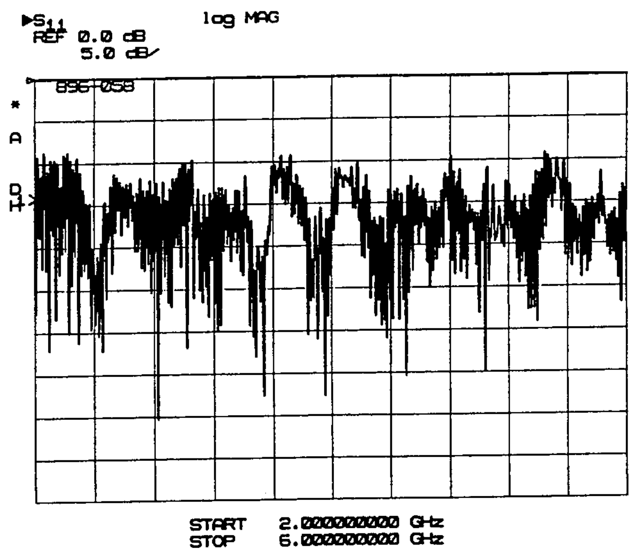
TASK 3.1: PVD MULTILAYER FILM FABRICATION

The only activity during the reporting period under this task was continued production of YBCO films on both sides of 2" dia. × 10 mil thick wafers for delay lines and filterbank channels. One change in the deposition process was made — using a single sputtering source instead of using both of the available sources. For the last two years, we were able to grow low-R_s films from a single target that were completely free of CuO "boulders" and a-axis-oriented outgrowths. These have been used primarily for multilayer structures in other programs where the thickness of each layer is approximately 2000 Å. In contrast, films required for this program must have a minimum thickness of 4000 Å to be significantly thicker than the penetration depth of YBCO at 77K. Therefore, two sputter sources had been used simultaneously to double the deposition rate. The tradeoff was that the second gun inevitably resulted in nucleation of some CuO precipitates. Since the number of films stockpiled for the remainder of the program permitted a lower rate of film production, we changed to slower single-source depositions. Since the sputtering system runs unattended, lower deposition rates do not add to labor costs while resulting in cleaner film surfaces.

TASK 3.2: MOCVD MULTILAYER FILM FABRICATION

Work at Emcore under this project was completed during the previous quarter. The primary objectives of this task were met with demonstrations of R_s-qualified YBCO films grown by MOCVD in a full-scale reactor on both sides of large-area wafers. The number of such wafers was too small to replace sputtered films in all of the devices





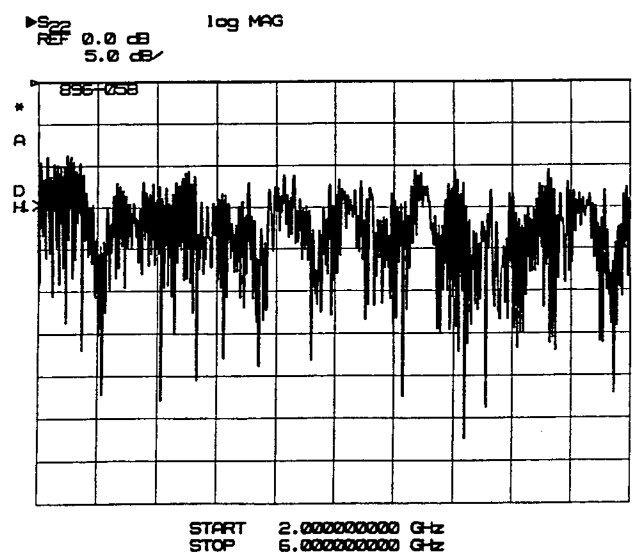


Figure 9 - Delay line DL-08 transmission and reflection responses *without* indium foil above the coplanar transition region.

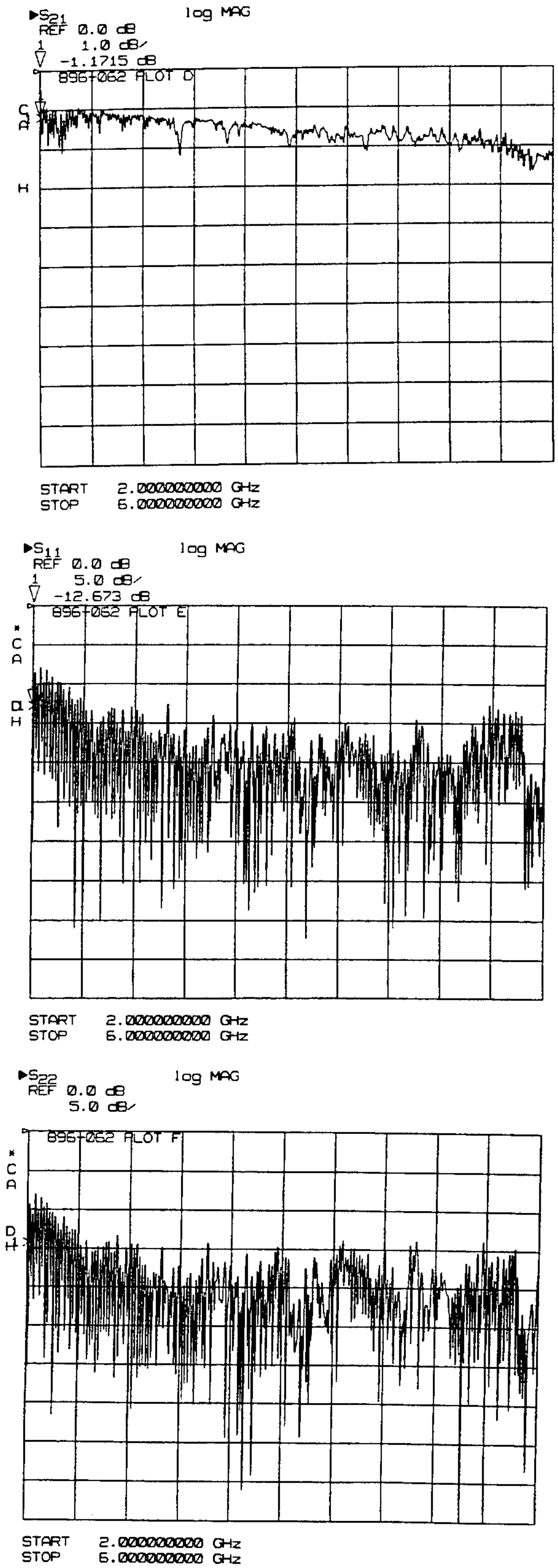


Figure 10 - Delay line DL-08 transmission and reflection responses *with* indium foil above the coplanar transition region.

produced in the program. However, fabrication and successful performance of a filter channel with two filters, two branchline couplers, and integrated thin-film loads demonstrated that the MOCVD films could withstand processing without degrading their desirable microwave properties.

Work at Northwestern University on new precursors with improved chemical stability and higher vapor pressures concluded during this reporting period. In addition to the synthesis at Northwestern of two new generations of precursor compounds, evaluation of new precursors in Emcore's full-scale reactor proved to be incompatible with maintaining an optimized deposition system so most of the precursor evaluation was performed at Northwestern. The effort at Northwestern during this quarter was limited to completion of papers for publication.

TASK 3.3: RF CHARACTERIZATION OF FILM PROPERTIES

RF surface resistance measurements were made during the quarter on YBCO films on 2-inch wafers at a rate of approximately three per week. Measurements were used primarily to check the quality of the second sides of double-sided YBCO films and ensure that the first side did not degrade during the second deposition. Our standard measurement technique was employed — a dielectric resonator with a reference YBCO film on a 2″ wafer and a film to be measured.

TASK 5.0: SWITCHED FILTERBANK

Tests of normal and Etch-Back FET switches were carried out at NASA Lewis in this quarter. Individual switch dies of design type 2 (normal FETs included for reference, since it was measured earlier), type 1, type 13 and type 15 were mounted using a conducting epoxy sheet (Ditac) on a niobium carrier. Figures 11 and 12 show sample characteristics of some of the Etch-Back FET switches. These measurements show very good isolation and insertion loss characteristics at 80 K.. They also demonstrate that the Etch-Back FET switches can withstand both vacuum and cryogenic temperatures, as earlier calculations indicated.

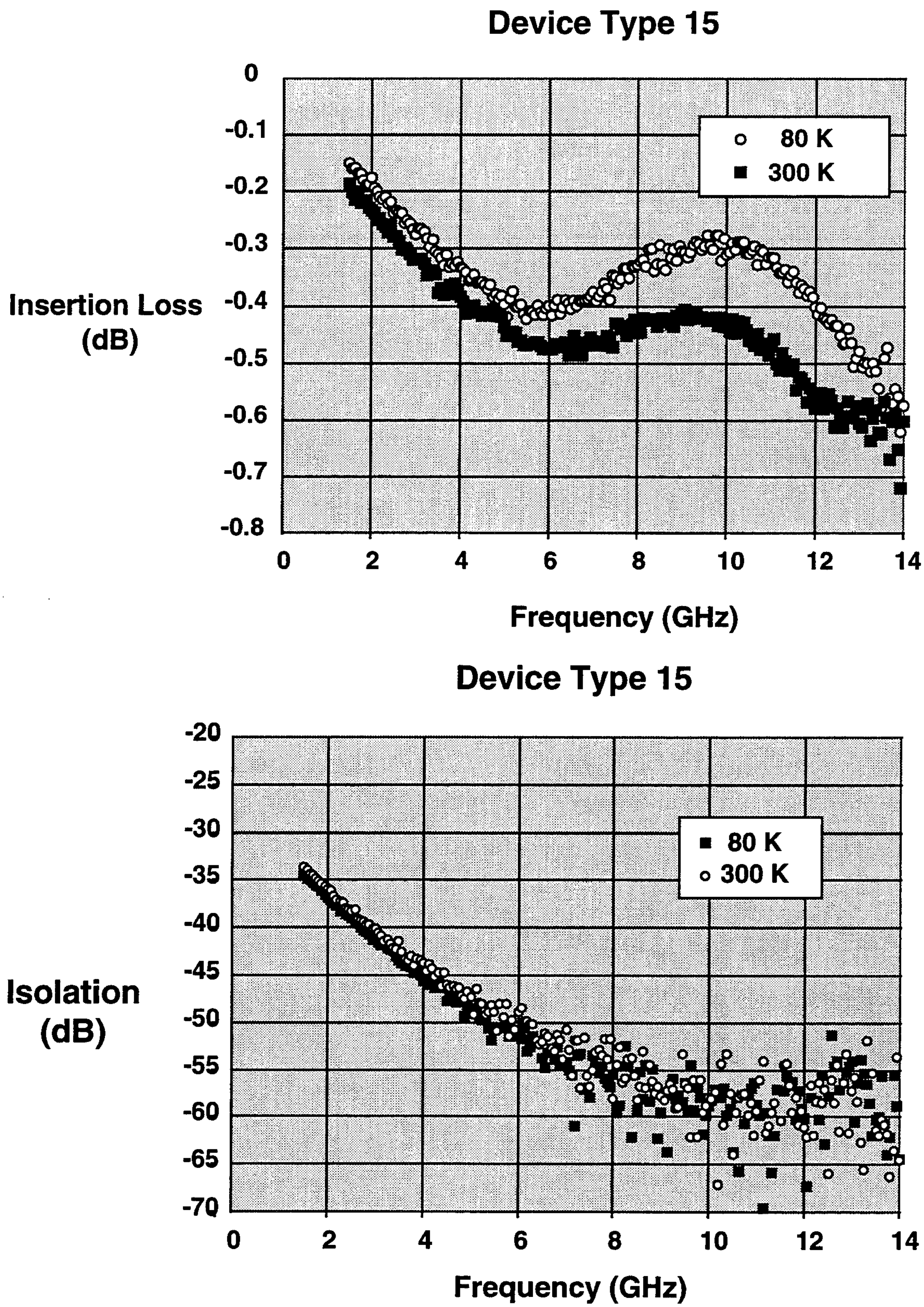


Figure 11 - Etch-Back FET switch type 15 isolation and insertion loss measured at room temperature and 80 K.

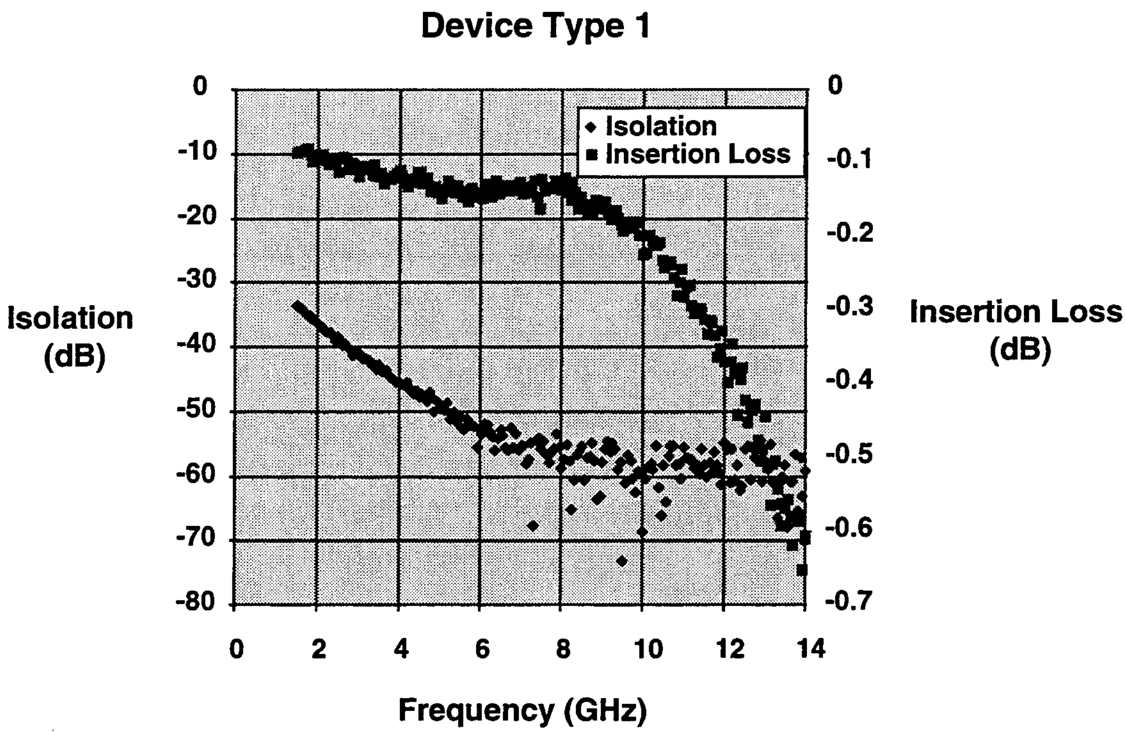


Figure 12 - Etch-Back FET switch type 1 isolation and insertion loss measured at 80 K. This switch has very low insertion loss.