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FIBER-OPTIC WORK AT NRAO GREEN BANK

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The authors traveled to NRAO Green Bank on July 1-2, 1991, to conduct fiber optics tests. Our objectives were to test methods of fusion splicing (especially with the new phase-stable fiber developed by Sumitomo Inc.), to determine the characteristics of fiber optic connectors from Radiall and JDS, to test an ORTEL laser transmitter and receiver, to examine the properties of phase stable fibers, and to become more familiar with fiber-optic techniques.

FUSION SPLICING:

Splicing was reasonably simple with the NRAO automated fusion splicing equipment (Sumitomo Type 35 #129). The key points were to have clean, well-cleaved fibers and to carefully align the fibers in the holding chucks of the machine. The tight jacket was removed from standard single mode fiber with a stripper (Sumiofacas JR 1 and 2 made by Sumitomo) and cleaned with isopropyl alcohol. The phase stable fiber was stripped by peeling back the outer yellow jacket (banana peeling style) and the stripper was used to remove the remaining inner clear jacket; acetone was used to clean the fiber (we should ask about a better solvent). The fiber was cleaved with a special high-precision cleaver (Fujikura Model 1990.1 #4658). Best results were obtained when cleaving was done last; the end of the fiber is easily damaged and should not be allowed to touch anything after cleaving.

The automated splicing machine did the detailed alignment of the fibers and the actual fusion. It was generally found that repeated applications of the arc, up to 2-4 times, improved the quality of the splice as determined by visual inspection and as determined by the automated splice loss estimation. In general, we were able to obtain splices with automated loss estimates of 0.02 db or better.

Although we were not able during this visit to measure the actual optical loss in our splices, losses were measured for pre-existing fusion splices made by NRAO. Four splices in the middle of a 130m cable were measured to have losses ranging from 0.1 to 0.3 db using an OTDR (Photon Kinetics High Resolution OTDR Model 4000 with Datalogger Model 4001A); the lowest loss that can be reliably measured with the OTDR is around 0.08 db. OTDR measurements of some of the on-site optical fiber cabling were also reviewed and splices exhibited losses in the above range. In all cases, fusion splices show little (<0.3 db) or no (<0.1 db) reflection in the OTDR; the majority show no reflection.

CONNECTORS:

Two types of fiber optic connectors, Radiall and JDS, were tested for loss and reflection characteristics. The Radiall connectors are currently being used in the Green Bank system and were already on the 130m cable available for our tests. Our JDS connectors were spliced onto one fiber of the 130m cable, onto a Radiall to JDS patch cable, and onto both ends of a 265m piece of delay stable fiber.

The Radiall connectors exhibited losses ranging from 0.6 to 1.1 db and reflection spikes ranging from 1 to 5 db (a total of 6 different connectors were examined). Multiple re-connections with a given connector were usually repeatable with a peak-to-peak variation of 0.18 db (results from about 50 measurements); the 0.6 to 1.1 db range in loss was mainly due to connector-to-connector variation, presumably due to the quality of the individual connectors. Cleaning the connector surface with alcohol and compressed air generally resulted in a reduced loss but repeated cleanings did not improve the performance.

The JDS connectors exhibited losses ranging from 0.1 to 0.3 db and reflection spikes ranging from 0.25 to 1 db (only two JDS connections were available for testing). Multiple re-connections with a given connector were usually repeatable with peak-to-peak range of 0.08 db (may be limited by the measurement capability). Cleaning the connector appeared to be especially important in reducing reflected power.

LASER TRANSMITTERS and RECEIVERS:

An ORTEL Model 3515A Laser Transmitter and Model 5515B-001 Receiver were tested. These devices are on loan to us from the manufacturer for test purposes. The Transmitter/Receiver combination had a net signal loss of some 42 db so the receiver was followed by cascaded linear power amplifiers (Mini-Circuits Models ZFL-1000LNB and ZFL-1000B) with a total gain of 44 db, giving the fiber-optic transmission system a net gain of 2 db.

Laser noise: The noise characteristics of the fiber-optic system were examined. Figure 1 shows the spectrum of the output from the system with a 0 dbm, 1.0 GHz input signal. The output signal level is +2.2 dbm. The noise plateau surrounding the signal at -38 dbm and the noise ramps down to -84 dbm are generated by the H/P Model 5105A synthesizer and 4X multiplier which were used to generate the input signal. Unfortunately, this synthesizer noise prevented the determination of laser noise at frequencies adjacent to the signal. Beyond the noise ramps, the laser noise is seen to be at a level of -84 dbm in the 30 kHz bandwidth of the spectrum analyzer. This corresponds to an Equivalent Input Noise level of -131 dbm/Hz, comfortably exceeding ORTEL's specification of <-125 dbm/Hz for the 1515A Transmitter. With this noise level, we should obtain an SNR of 73 db for a 0 dbm LO reference signal. For tolerable phase jitter we need an SNR of 68 db. If necessary, a higher SNR could be obtained with a higher input signal level. At higher input signal levels, the laser noise is expected to increase but we were unable to generate a high enough input signal level to observe this effect.

Intermodulation Distortion: The Input Third Order Intercept was measured at 1.0 GHz to be +28 dbm for the fiber-optic system. This compares well with ORTEL's specification of +25 dbm for the 1515A transmitter. The Second Order Intercept was +48 dbm and the Fourth Order Intercept was unmeasurable.

PHASE STABILITY:

The 1.0 GHz input signal was split with one side going directly to Port A of an H/P 8405A Vector Voltmeter and with the other side going through the laser transmitter, 5m pigtails of normal SM fiber, 265m of Sumitomo phase-stable fiber, the fiber-optic receiver, cascaded RF amplifiers, and then to Port B of the Voltmeter. The input signal was generated by the synthesizer mentioned above and was locked in frequency to the Observatory's hydrogen maser. No particular care was taken to physically or thermally stabilize the system. Flexible cables and SMA or BNC connectors were used. Any disturbance of the cable or connectors resulted in significant phase jumps.

No quantitative measurements were made on the phase-stable fiber. However, it was found that if a hair dryer was directed at one of the 5m pigtails of normal fiber, a phase shift of several electrical degrees resulted immediately; when the hair dryer was directed at the coil of phase-stable fiber and kept on it long enough to heat the coil until it was quite warm to the touch, no measurable phase shift occurred. We judge that the phase-stable fiber is at least two orders of magnitude more stable than the normal fiber.

We allowed the phase test to run undisturbed for about an hour. The results are shown in Figure 2. The slow phase drift is caused by the fact that the system, and especially the RF amplifiers, were turned off until just before this test. The slow drift during the hour is a typical warm-up drift.

Phase jitter of about 0.08x peak-to-peak is seen. This is very likely a result of the -38 dbm noise plateau over the 2.6 MHz band adjacent to the signal which was seen in Figure 1. This noise plateau is generated by the H/P 5105A synthesizer, a synthesizer which is famous (or infamous) for generating such noise levels. One can easily calculate that the noise plateau should yield an SNR of w 21 db or w 0.5x RMS of high frequency jitter. This high frequency jitter would be smoothed by the unknown time response of the vector voltmeter and recorder and could well result in the 0.08x peak-to-peak jitter that was recorded.

FUTURE PLANS:

In early August, when we have received our pair of fiber-optic receivers and photodiodes, our optical isolators, and our length of phase-stable fiber-optic cable, we would like to return to Green Bank for further tests. We can cut our test fiber in two and test the relative phases through two fiber-optic systems; we can test the variation of phase with signal frequency to check for any standing wave effects; and, with a better signal source, we could try locking an X-band phase lock loop to the output of the fiber-optic system and check the phase jitter in the loop. Assuming that these tests are successful, we would then take the system to Hat Creek for its final proof by an actual astronomical observation.

We wish to thank the Green Bank staff and, especially, Bill Shenk and Steve White for their advice and assistance.

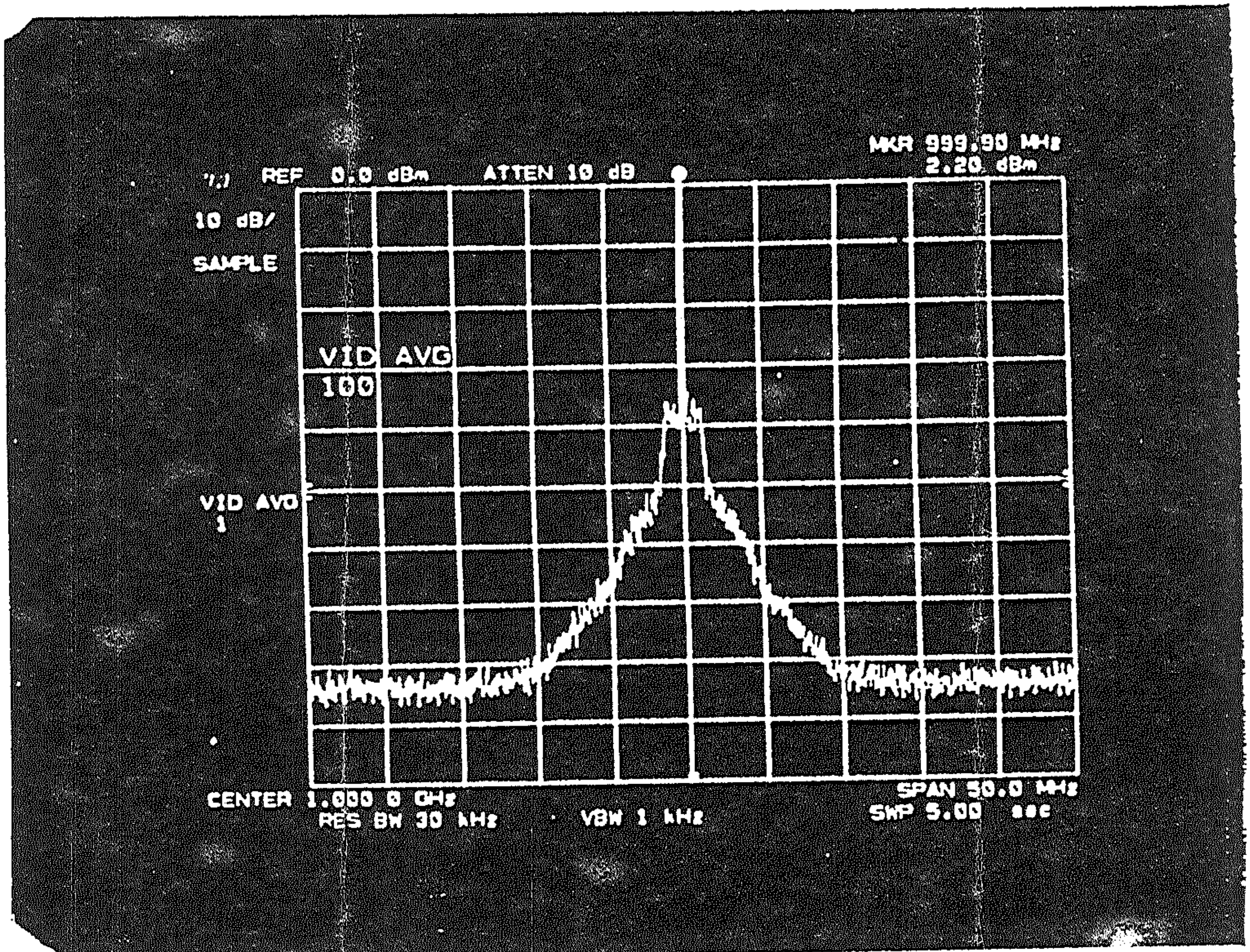

Figure 1. The output spectrum of the fiber-optic link with a 0 dbm, 1.0 GHz input signal. This output spectrum is essentially identical to the input spectrum. The output noise floor is at -84 dbm. It was found to be raised above the -87 dbm noise floor of the spectrum analyzer by wide-band noise generated in the link.

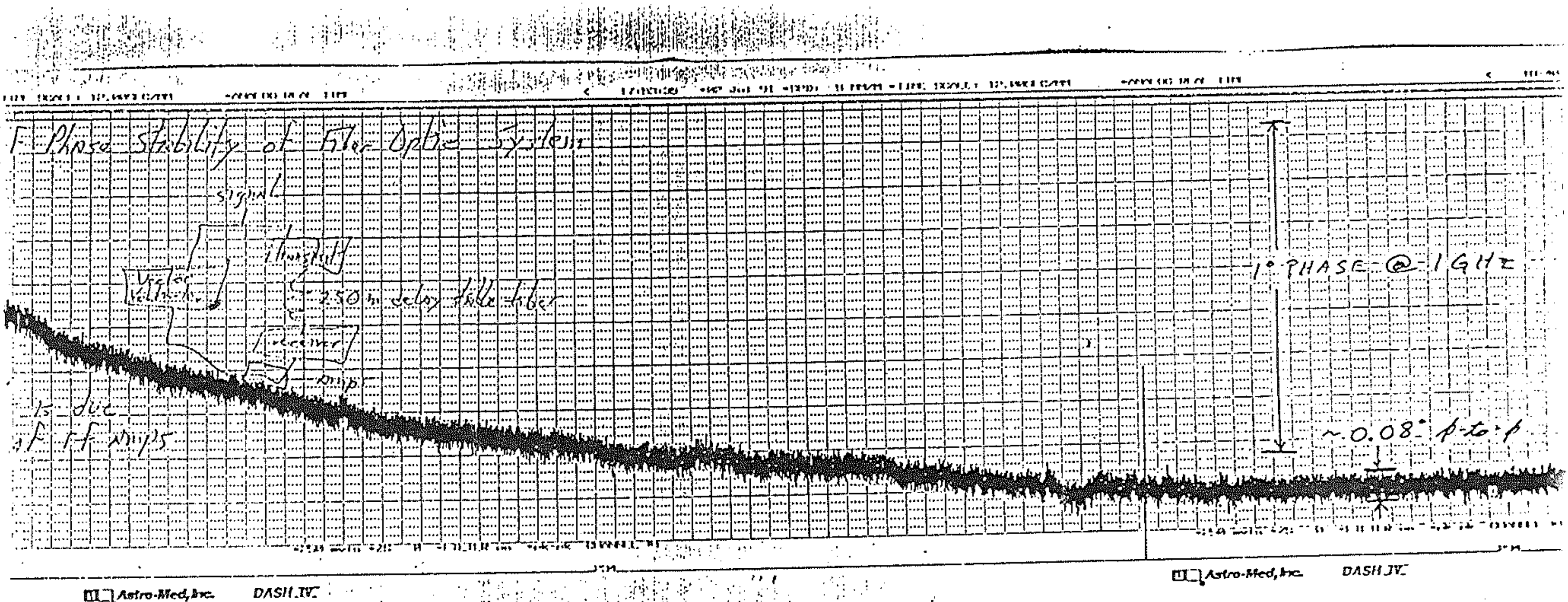

Figure 2. The phase stability of a 265m fiber-optic link. The recording is about one hour long. The slow phase drift is caused by the fact that the system was turned on just previous to this recording.