Academia Sinica, Institute of Astronomy & Astrophysics
SMA Project

Subject:	**Date:**	**From:**
Remote Monitoring of RF Signals within the Antenna Cabins	20 January 2006 ASIAA-HI-001	Derek Kubo

To:	**cc:**		**Location/Phone:**
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Purpose: The SMA telescope is presently in a stage of progressive refinement to improve its reliability and sensitivity. During this process we've identified a number of key RF test points in the antenna cabin which represent the health and status of the receiver and IF/LO system. One present problem, however, is that it is relatively labor intensive to configure the monitoring test hardware for any one particular antenna. This is particularly true for the test points which are physically located within two layers of mechanical enclosures[1]. The problem is compounded for 8 antennas, hence we generally only perform these tests after a problem has surfaced. Since the cost of a remote monitoring system will likely be a non-trivial expenditure this memo describes the proposed approach along with alternate cost options.

Summary: An approach for monitoring specific critical signals within the antenna is proposed in this memo. The primary cost driver for this approach is the spectrum analyzer which comes in three basic categories from lowest to highest cost: a) low frequency < 3 GHz; b) high frequency > 10 GHz but unable to measure low phase noise; c) high frequency with the ability to measure phase noise. Since we presently have three analyzers capable of measuring high frequency phase noise, I am recommending a hybrid approach consisting of b) and c).

Overview: Figure 1 describes the proposed test setup in an antenna cabin which has the capability to monitor one of twenty signals using a spectrum analyzer. Items in blue indicate the monitoring hardware. A more detailed discussion on the selection of a spectrum analyzer is provided later in this memo. The test signals I am recommending to monitor are as follows:

   a) Gunn 109 MHz IF monitor (8 possible signals)
   b) 109/200 MHz monitor references for both LO1 and LO2 (2 signals)
   c) 200 MHz YIG PLL error monitor for YIG1 and YIG2 (2 signals)
   d) YIG1 and YIG2 monitor outputs (2 signals, 5.3 to 8.7 GHz)
   e) IF1 and IF2 post amplified and leveled monitor outputs (2 signals, 4 to 6 GHz)
   f) MRG LO1 and LO2 monitor reference (1 signal, 5.5 to 8.5 GHz)

These test points permit monitoring of the signals without interruption through the use of built-in directional couplers allowing simultaneous measurements with observations. For items b) through f), the test points are physically located within the inner Rose chassis' and must be brought out through the use of feed-through connectors and coaxial cables. All switches will be TTL controlled and of terminating types[2] to prevent reflection of unmonitored signals. Switches S3 and S4 will likely be located within the Hoffman enclosure to minimize the number of physical penetrations and to reduce potential EMI leakage into the cabin.

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[1] For thermal stability
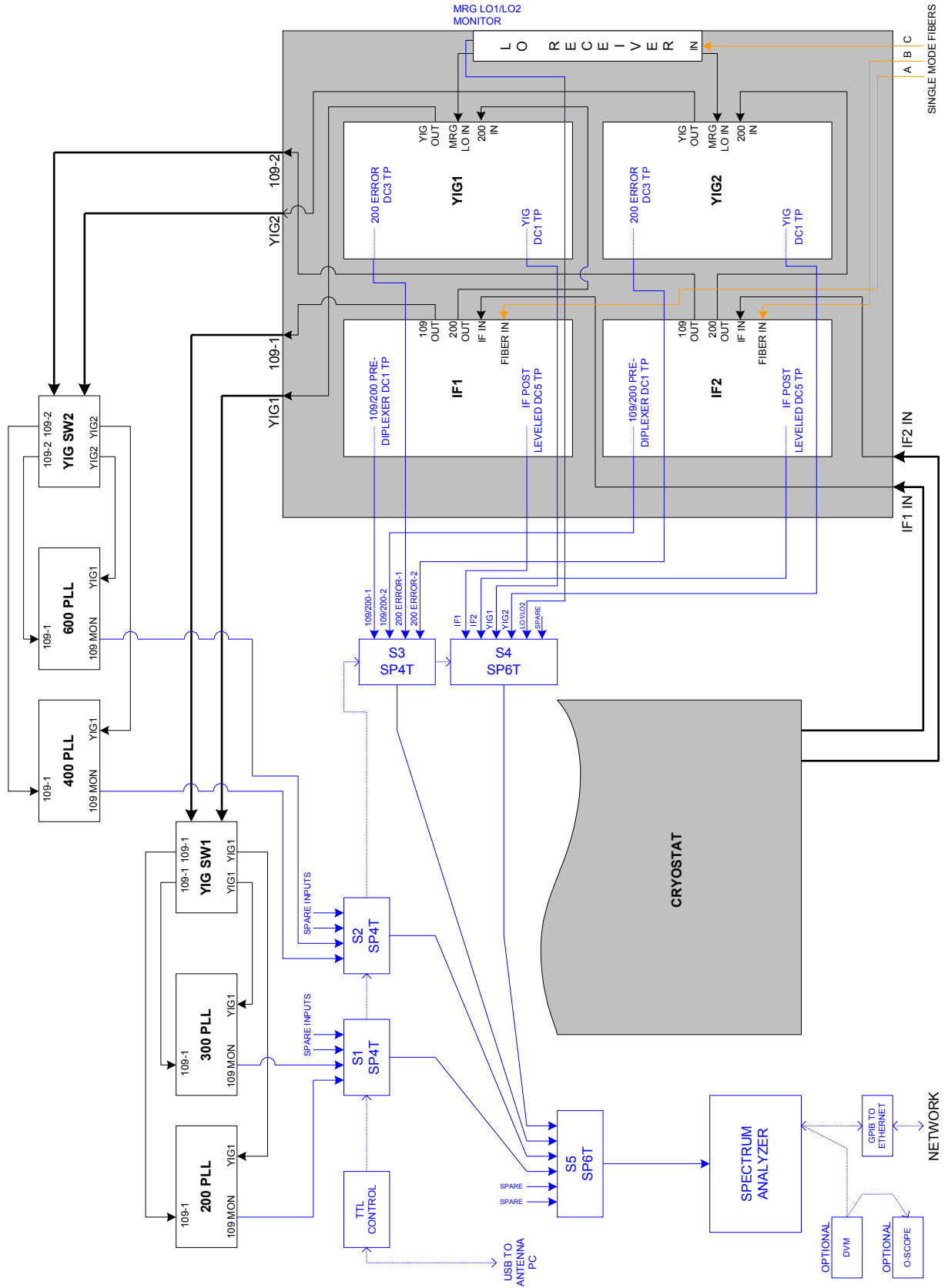[2] All unused inputs terminated to 50 Ohms

FIGURE 1 PROPOSED ANTENNA MONITORING SYSTEM

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Gunn Monitor: Each Gunn PLL has a 109 MHz IF monitor test point which represents the 109 MHz error signal in the loop. Switches S1 and S2 of Figure 1 will be used to monitor any one of these eight potential Gunn PLLs, although as of this writing there are only four (200, 300, 400 and 600 Gunn PLLs). I am presently proposing to install these two switches on the top of the optics cage near the YIG switches. Figure 2 represents a recent 109 MHz IF monitor plot seen on antenna 2 300 GHz PLL[3]. Of particular interest in this plot are the: tone amplitude; distance to noise pedestal; shape of noise pedestal; and presence of spurs. Another associated plot (not shown) is the L(f) which represents noise power (dBc/Hz) as a function of frequency, and its integrated phase noise number. In addition to providing quantitative metrics, this test point can be used to help lock a troublesome Gunn PLL. This is normally accomplished by setting the span to 100 MHz and observing whether the tone is too high or too low.
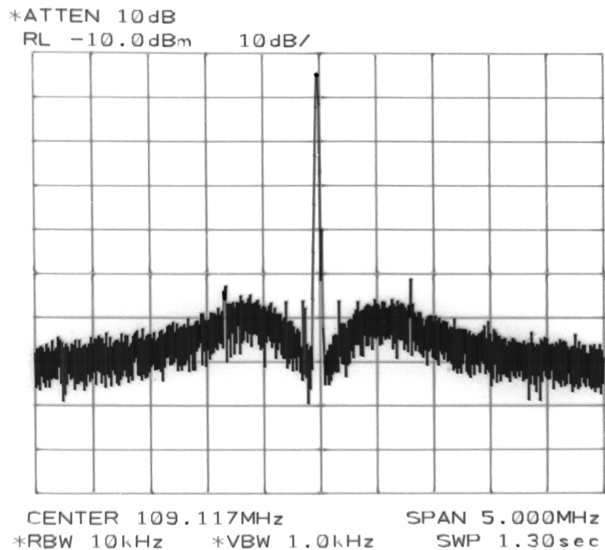

Figure 2 Gunn PLL 109 MHz IF Monitor

Low Frequency Reference Monitors: Switch S3 of Figure 1 will be used to select the pre-diplexer 109/200 MHz test points from the IF1 and IF2 assemblies (DC1 of Figure 5), and the 200 MHz error signal from the YIG1 and YIG2 assemblies (DC3 of Figure 6). The pre-diplexer test point is a convenient place to look because it contains both the 109 and 200 MHz references for the Gunn and YIG PLLs, respectively. There are no active devices between this test point and their final destinations so it is good representation of the signals. Figure 3 represents an example of a 200 MHz reference for antenna 5 YIG1 before and after cleaning of an optical fiber (see test log #10077 for technical details). This improvement yielded more than a factor of 2 reduction in the YIG output phase noise.
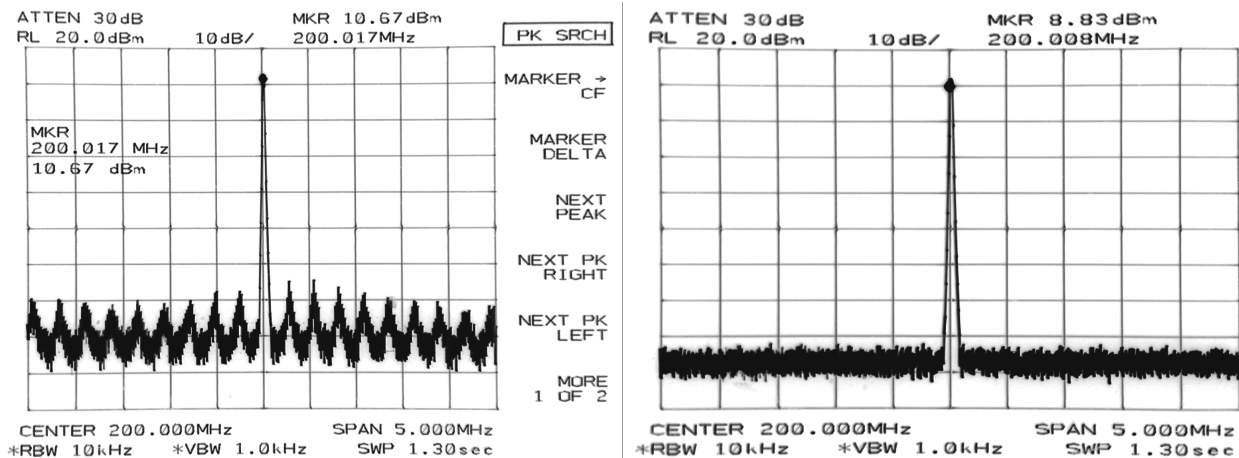

Figure 3 200 MHz Reference, Left – Before Cleaning, Right After Cleaning Fiber-A

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[3] Walsh function on

The 200 MHz error signal from the YIG assembly is similar to the 109 MHz error signal for the Gunn PLL. At present, this test point is not often looked at because access is not convenient.

High Frequency Monitors: Switch S4 of Figure 1 will be used to select the post amplified and leveled IF1 and IF2 signals (DC5 of Figure 5), coupled YIG1 and YIG2 outputs (DC1 of Figure 6), and the MRG LO1 and LO2 monitor (J1 of Figure 7). Live monitoring of the IF signals could prove to be quite useful. Some examples:

a) Characterization of Y-factor[4] as a function of IF frequency
b) Comparisons of IF flatness between antennas at various observing frequencies
c) Amplitude verses frequency comparisons between antenna and C1DC
d) Holography beacon search
e) Look at receiver output as a means to avoid oscillation during tuning, particularly for 600 GHz

The YIG outputs are looked at frequently to quantify the phase noise of the reference provided to the Gunn assembly. This is because the phase noise requirement at the YIG output is very stringent with a self imposed spec of 0.25 degrees RMS[5], and a goal of 0.20 degrees. Although 0.25 degrees does not seem like much, it translates to approximately 8, 12, and 21 degrees at our typical final LO frequencies of 225, 340, and 685 GHz, respectively. And that ignores the Gunn PLLs phase noise contribution. Figure 4 shows the YIG1 output spectrum and L(f) plot for antenna 1 taken on June 16, 2005. The YIG1 phase noise was measured to be 0.23 degrees RMS.
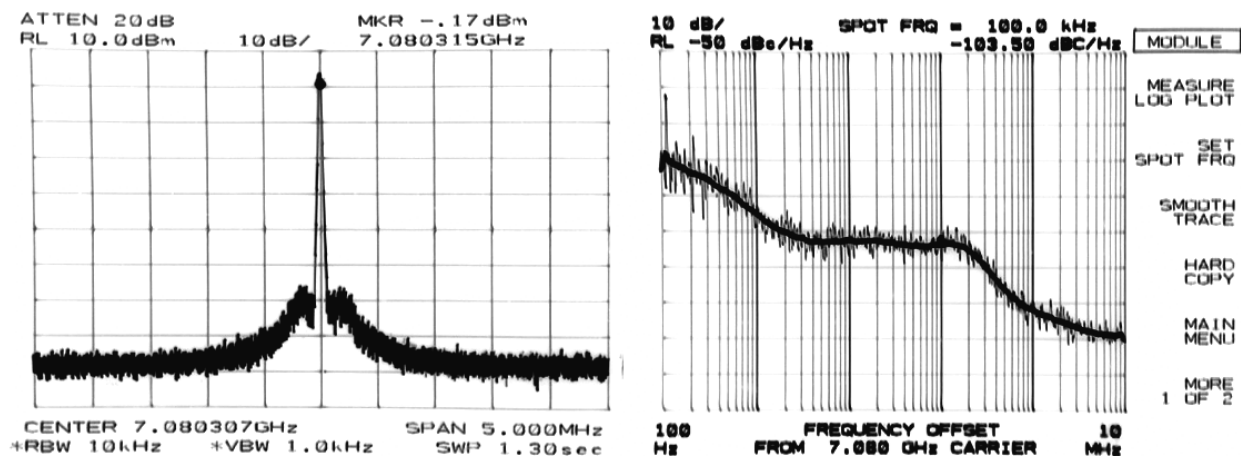

Figure 4 Antenna 1 YIG1 output spectrum and L(f)

When a phase noise problem is detected on the YIG output, we look at the 200 MHz input reference (described in the previous paragraph) and the MRG LO input reference. The MRG LO is often compromised in SNR due to a higher than desired fiber-C loss but our current DERS monitoring system cannot detect this condition.

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[4] Ambient Load vs. sky
[5] SSB, integrated from 100 Hz to 10 MHz

Spectrum Analyzer: A number a items need to be considered for the selection of a spectrum analyzer which include the following:

a) Cost
b) Usable frequency up to 9 GHz
c) Low noise floor to characterize SNR
d) Ability to measure L(f) and integrated phase noise[6]
e) Portable

We presently have three HP 8563E[7] spectrum analyzers in Hilo/Mauna Kea which covers 9 kHz to 26.5 GHz and is used for most our measurements. The next model below this is the HP 8562E which covers 30 Hz to 13.2 GHz. Quotes[8] for used units are provided in Table I for a quantity of five units, although it does not appear that I received much of a discount for that quantity. As suspected the cost of this spectrum analyzer is quite high. Some positive attributes of this analyzer are that: we already have three compatible units; as frequent users of this equipment we are quite familiar with its operation and capabilities; it does provide us with all the capability necessary to checkout the RF system. Another analyzer capable of measuring phase noise is the Rohde & Schwarz model FSP13 which covers the range of 9 kHz to 13.6 GHz. It appears to be a very nice unit, however, the lowest used cost I have found so far is $23,466 at www.usedtestgear.com. Its new list price is $34,980, quite similar to the HP 8562E MSRP of $34,170.

Table I Quotes for HP 8562E Spectrum Analyzer

SUPPLIER	MODEL, OPTIONS	$ EACH	$ 5 UNITS
Calright Instruments	8562E	$24,500	$122,500
Test Equipment Connection	8562E, 001, 007	$26,995	$134,975
Tucker	8562E	$19,000	$95,000
ValueTronics	8562E	$19,995	$99,975

A second alternate solution would be to purchase lower cost spectrum analyzers which covers the desired frequency range but without the ability to measure phase noise. Some units I have used in the past are the Tektronix model 492P and 2754. The 492P is a portable unit similar in size to the HP 8562E and covers 50 kHz to 21 GHz. Cost is $7,500 used at Tucker Electronics, much cheaper that the HP or RS models. One problem with selecting an unfamiliar analyzer is that it is difficult to assess its performance under actual use conditions. For example, we currently have a handheld Anritsu MS2711B spectrum analyzer which operates over 100 kHz to 3 GHz. This unit was purchased[9] in 2002 for $7k but is rarely used because of its awkward menu and slow sweep speed. I recommend obtaining an analyzer on loan for evaluation prior to make an expensive purchase in the future.

Remote Software Control: I am currently leaning toward a Labview interface to control and monitor the spectrum analyzer. Doing so will help decouple our effort in Hilo from the software expertise in Cambridge. I am aware of three licensed copies of Labview at our Hilo facility. The

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[6] to less than 0.1 degrees RMS (100 Hz to 10 MHz), inherently implies low phase noise internal LO and narrow resolution BW
[7] 9 kHz to 26.5 GHz
[8] I did not ask for GSA discount
[9] ASIAA, RCUH PO Z590366

use of Labview won't preclude the future development of custom software to interface directly through the operational telescope software.

Estimated Material Costs: An estimate of the material costs for a single antenna, excluding the spectrum analyzer, is shown in Table I below. For eight antennas, $4.9k x 8 = $39.2k.

Table I Estimated Material Costs for One Antenna (excludes spectrum analyzer)

| ITEM	QTY	EST UNIT $	TOTAL $
S1 – S3, SP4T Terminated Switch, 500 MHz	3	350	1,050
S4, S5, SP6T Terminated Switch, 10 GHz	2	850	1,700
Low Frequency Coax Cables, Flex	8	25	200
High Frequency Coax Cables, Semi-rigid	5	50	250
High Frequency Coax Cables, Flex	2	250	500
SMA Bulkhead Feed-through Connectors	10	15	150
GPIB to TTL Control Box	1	500	500
GPIB to Ethernet Box	1	500	500
GPIB Cables	2	25	50
TOTAL			$4,900

Conclusions and Recommendations: If cost were not an issue I would recommend the purchase of five more HP 8562E spectrum analyzers. However, in order to reduce costs, we could go with five more Tektronix 492As. A hybrid system consisting of two different spectrum analyzers will require two independent software controllers, and we will have to keep track of which type of analyzer is in each antenna. The total cost comparisons for these two scenarios are as follows:

Scenario 1: 5 x $20k + 39.2k = $139.2k
Scenario 2: 5 x $8k + 39.2k = 79.2k

The exact decision of how many of which model spectrum analyzer does not have to be made now. However, I do recommend that we outfit one or two antennas for monitoring before the end of first quarter 2006. This will involve the procurement and installation of the switches shown in Figure 1, and physical modifications of the antenna IF/LO hardware for the installation of the RF bulkhead feed-through connectors. Interface to our HP 8563E spectrum analyzer's GPIB will be via a National Instruments GPIB-ENET/100 interface box, which we presently have one of in Hilo. All of the test points shown in Figure 1 have been monitored manually in the past and we don't expect to run into many RF problems with the switches and cabling as long as we maintain good impedance matching and high isolation.

One natural outcome of this approach would be that we continue to outfit subsequent antennae with the necessary switches and cabling hardware. We could then use our existing three spectrum analyzers to monitor any three antennas which will be quite useful.

FIGURE 5 ANTENNA IF ASSEMBLY, 10340050000
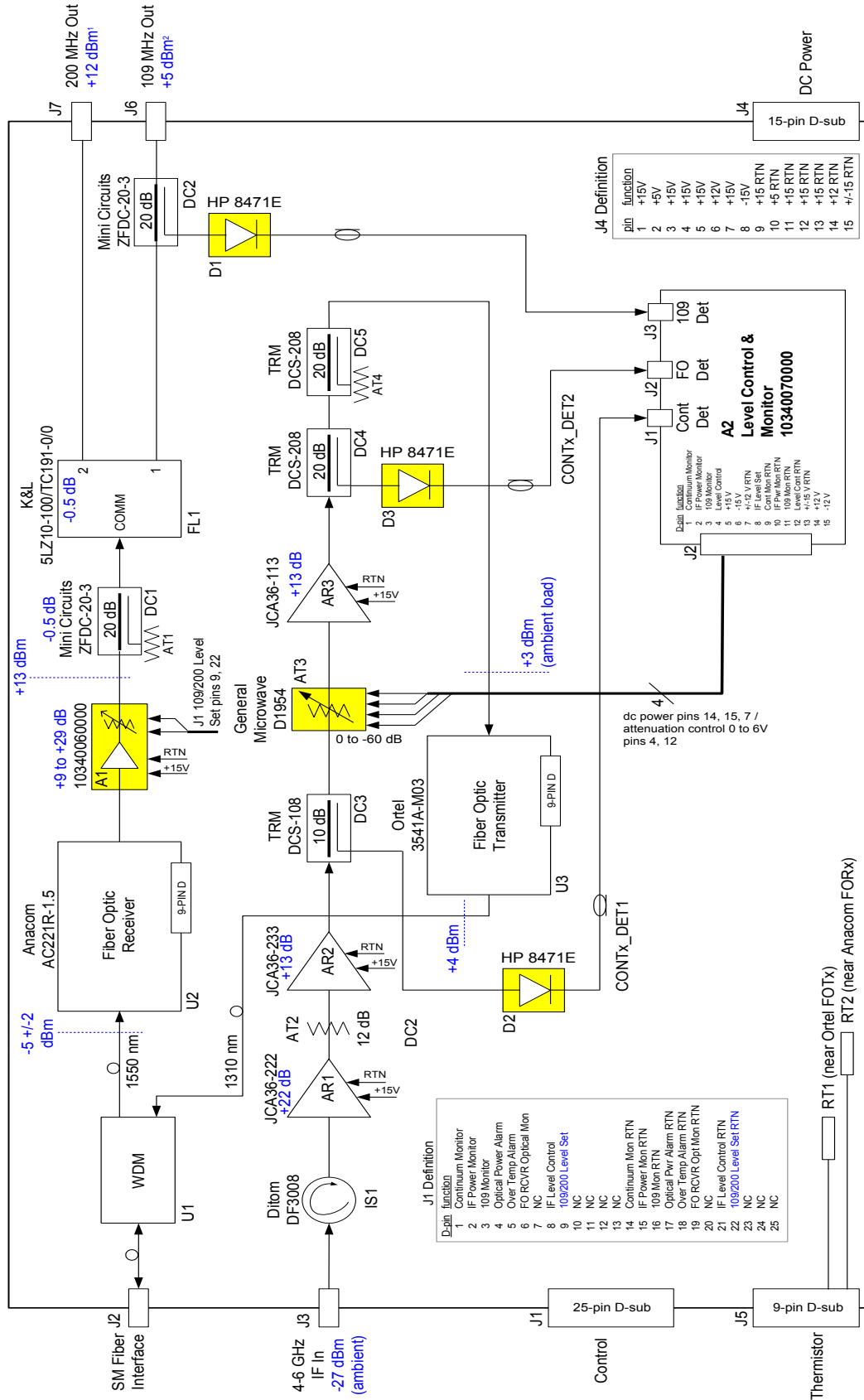
Notes:
1) IF power levels shown are for ambient load conditions (highest expected levels from receiver output).
2) Variable attenuators and power detectors are highlighted in yellow.
3) There is a power profile disparity in the IF path between the spec gains and empirical measurements. This dwg will be updated when the correct information is obtained.

ant_if_blk
rev 2005dec30
dkubo

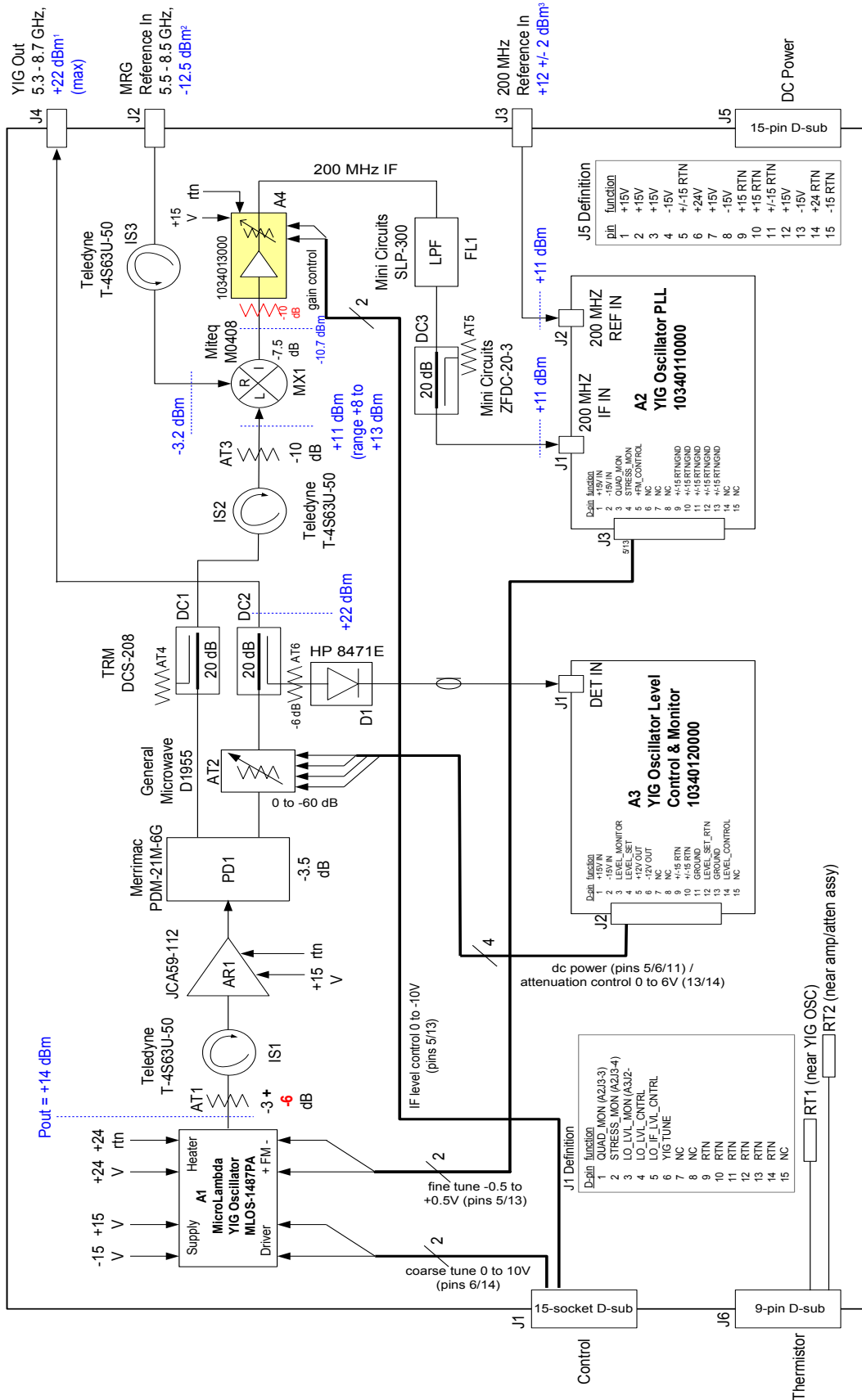FIGURE 6 YIG OSCILLATOR ASSEMBLY, 10140030000

Notes:
1) YIG output power is controlled by Receiver Group (via AT2) to optimize LO level to Gunn PLL.
2) MRG reference input level is controlled by LO Receiver plate attenuator.
3) 200 MHz reference input level is controlled by Antenna IF assy attenuator.
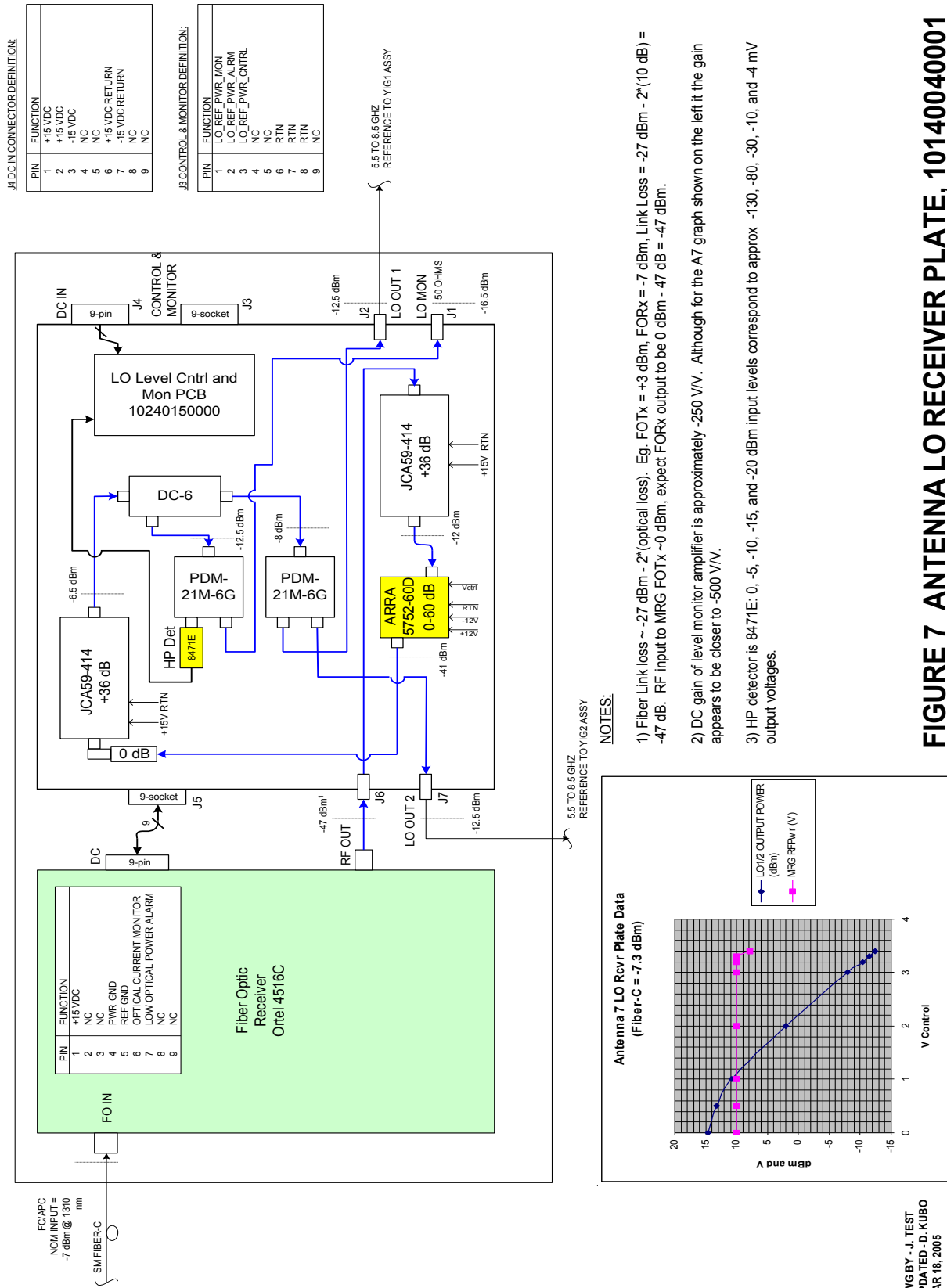
yig_osc_blk
rev 2005dec30
dkubo

J4 DC IN CONNECTOR DEFINITION:

PIN	FUNCTION
1	+15 VDC
2	+15 VDC
3	-15 VDC
4	NC
5	NC
6	+15 VDC RETURN
7	-15 VDC RETURN
8	NC
9	NC

J3 CONTROL & MONITOR DEFINITION:

PIN	FUNCTION
1	LO_REF_PWR_MON
2	LO_REF_PWR_ALRM
3	LO_REF_PWR_CNTRL
4	NC
5	NC
6	RTN
7	RTN
8	RTN
9	NC

PIN	FUNCTION
1	+15 VDC
2	NC
3	PWR GND
4	REF GND
5	OPTICAL CURRENT MONITOR
6	LOW OPTICAL POWER ALARM
7	NC
8	NC
9	NC

NOTES:

1) Fiber Link loss ~ -27 dBm - 2*(optical loss). Eg. FOTx = +3 dBm, FORx = -7 dBm, Link Loss = -27 dBm - 2*(10 dB) = -47 dB. RF input to MRG FOTx ~0 dBm, expect FORx output to be 0 dBm - 47 dB = -47 dBm.

2) DC gain of level monitor amplifier is approximately -250 V/V. Although for the A7 graph shown on the left it the gain appears to be closer to -500 V/V.

3) HP detector is 8471E: 0, -5, -10, -15, and -20 dBm input levels correspond to approx -130, -80, -30, -10, and -4 mV output voltages.

FIGURE 7 ANTENNA LO RECEIVER PLATE, 10140040001

Antenna 7 LO Rcvr Plate Data
(Fiber-C = -7.3 dBm)