Submillimeter Array Technical Memorandum

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Notes on Built-in IF/LO Test Capability

1. INTRODUCTION

The motivation for the concept described in these notes is an attempt to simplify and consolidate the set-up and maintenance of the IF and Local Oscillator Distribution System. Since the SMA is complex instrument, physically scattered over a wide area in a relatively inaccessible location it is worth investing a reasonable amount of time and effort to implement end-to-end transmission tests which can be performed by maintenance personnel from the control building consoles (or even from a remote site, with the proper safeguards). Although the primary purpose of the instrumentation is the evaluation of the performance of the IF and LO transmission facilities, the test procedures can be extended to encompass the correlator baseband converters with the addition of suitable detectors or test points following each downconverter.

2. THEORY OF OPERATION

Figure 1 is a simplified block diagram of the IF/LO Distribution System, showing the major components in the control building, central vault and one of the six antennas. The Master Reference Generator in the Control Building is the source of two independently tunable master reference frequencies in the range 6.05 to 8.5 GHz which are transmitted through a common optical laser link to all antennas. Each antenna, in turn, uses a pair of Reference Signal Generators to phaselock two YIG oscillators (one in each Reference Signal Generator) to the master reference signals. The Reference Signal Generator YIG oscillators are pretunable in an open loop mode, under remote processor control, with an accuracy in the order of 5 MHz. The phaselock loop normally takes over upon completion of the pretuning cycle, but is important to note that moderately accurate standalone microwave signal sources are built into the antenna electronics system. The outputs of the Reference Signal Generators are fed to the Gunn oscillator harmonic mixers, for frequency multiplication into the 70 to 150 GHz range.

In the opposite direction, the IF Distribution subsystem accepts the 4 to 6 GHz IF output of each receiver, amplifies the broadband signals to the optimal level for modulation of the laser transmitters, and transmits each IF signal over a separate fiber to the optical patch panel in the central vault. The IF signals are routed through the patch panel; a passive, manually-operated switching matrix, to the control building and the correlator baseband converters.

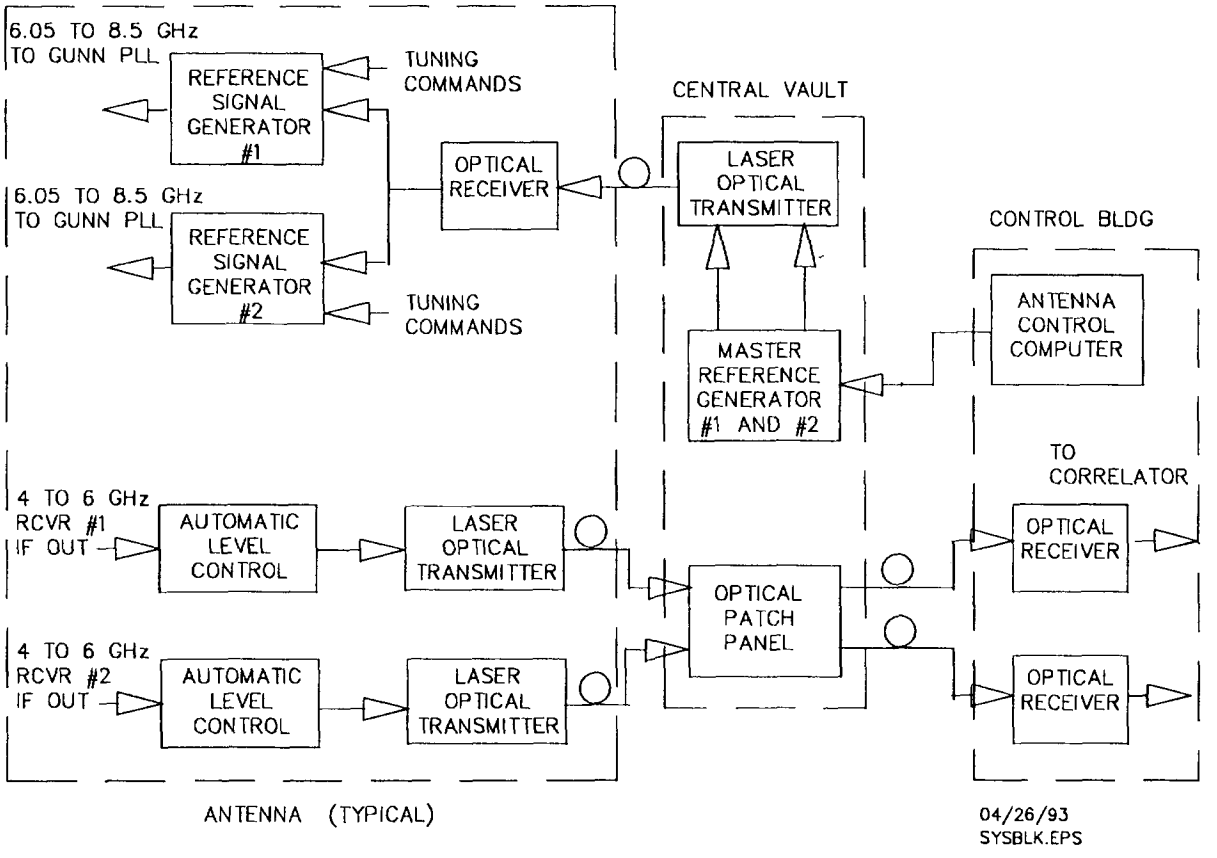

Figure 1 SMA IF/LO DISTRIBUTION SYSTEM - SIMPLIFIED BLOCK DIAGRAM

2.1 IF Open Loop Test Mode

The proposed IF/LO Built-In-Test (BIT) exploits the presence of two remotely-tunable YIG oscillators in each antenna. The operational function of these oscillators is, of course, to provide the 6.05 to 8.5 GHz reference frequencies for the Gunn-diode local oscillator sources. However, in the open-loop mode, the YIG oscillators can be remotely tuned over the entire 2 to 10 GHz range without modification to the Reference Signal Generator hardware. Therefore, by the addition of suitable microwave switches at the inputs to the IF laser transmitters and directional couplers at the outputs of the YIG oscillators, a simple and straightforward means of injecting a known test signal into the IF channels can be implemented. The frequency accuracy in this mode is sufficient to troubleshoot individual correlator chunks and to verify the allocation of the tunable baseband converters to specific locations in the IF spectrum. The major benefit of this approach is that for very little additional cost and complexity, operating personnel can readily check out the gross performance of the IF distribution subsystem without leaving the comfort of the control room or transporting special test equipment to the antenna sites. In addition, only relatively simple modifications to the existing PMAC software are needed to automate a complete chunk-by-chunk test of the correlator baseband converters. A more detailed description of hardware implementation of the open-loop mode is deferred to Section 3 below.

2.2 IF Coherent Test Mode

With a very moderate increase of hardware complexity it is possible to substantially enhance the sophistication and flexibility of the BIT. The existing YIG oscillators in the Reference Signal Generators are primarily intended to phaselock to master reference signals in the 6.05 to 8.5 GHz range. However, the present hardware design will accommodate reference signals in the 4.0 to 6.0 range, possibly with some minor degradation of phase noise characteristics. It is therefore possible to generate a set of coherent IF test signals, all phaselocked to the Master Reference Generator, if the MRG tuning range is extended to cover the IF distribution band. The extension, which would be used only in the coherent test mode, is a straightforward adaptation of the existing MRG design. The coherent test capability provides the basic "continuity" measurement described above as well as certain unique functions:

2.2.1 IF Transmission Phase Stability. The mechanical and temperature stability of the master reference chain is more than adequate to validate the performance of the IF distribution links from the antenna to the correlator input A simple vector network analyzer measurement, using one link as the reference, will quickly identify and isolate IF transmission problems. Again, by the addition of suitable software, the phase stability measurement can be automated.

2.2.2 Vernier Delay. The coherent test mode is well suited for calibration and maintenance of the new vernier delay circuits. By holding the delay in the reference channel constant, the phase slope of the delay unit under test can be determined and the corresponding time delay readily calculated. A simple program which cycles each vernier delay unit through its eight binary steps can completely characterize the delay lines without operator intervention.

Details of the hardware design of the coherent test mode are shown in Section 3 below.

2.3 Limited-Range IF Coherent Test Mode

There is a middle ground between the simple Open Loop Mode and the substantially more complex Coherent Mode. The Master Reference Generator can be tuned over the 5.5 to 5.95 GHz range without modification to the existing hardware. The control software must include a test module to permit this intrusion into the otherwise forbidden IF transmission band, but the changes appear to be very minor. The correlator baseband converters under test must reside in, or by moved into, the 5.5 to 5.95 GHz band in order to perform the functions described in Paragraph 2.2 above, but this also appears to be relatively straightfoward, given the flexibility of the current correlator design.

2.4 LO Reference Test Mode

The LO Reference Test is more a specialized application of the IF Coherent Test configuration than a test mode in its own right. The hardware arrangement is identical to that of the coherent IF mode, except that Reference Signal Generator YIG oscillators are tuned and phaselocked within the master reference band, 6.05 to 8.5 GHz.

The accuracy and stability of the measurements on the master reference frequencies which can be performed in the LO Reference Test Mode is quite limited, but the capability may be useful during the initial set-up and troubleshooting phases of the array installation. The limitations are imposed by:

2.4.1 The long fiber runs from the antenna sites to the central vault and from the vault to the control building. These transmission lines are not used in actual operation of the reference distribution subsystem.

2.4.2 The temperature errors introduced by the IF laser transmitters and receivers used to echo the master reference signal back to the control building. It should be noted that the reference signal laser transmitter is common to all six antennas and that the reference optical detectors in the antennas are temperature controlled.

3. HARDWARE CONFIGURATION

3.1 IF Open-Loop Test Mode

The additional components required to implement this test mode are microwave switches and a directional coupler, all located in the antenna Reference Signal Generator. Figure 2 is a simplified block diagram of the antenna electronics, showing only those items relevant to the IF test capability. For clarity, only one of the two Reference Signal Generators in each antenna is shown; the second RSG is identical. Those new items required only for the IF Test mode are enclosed in dotted lines.

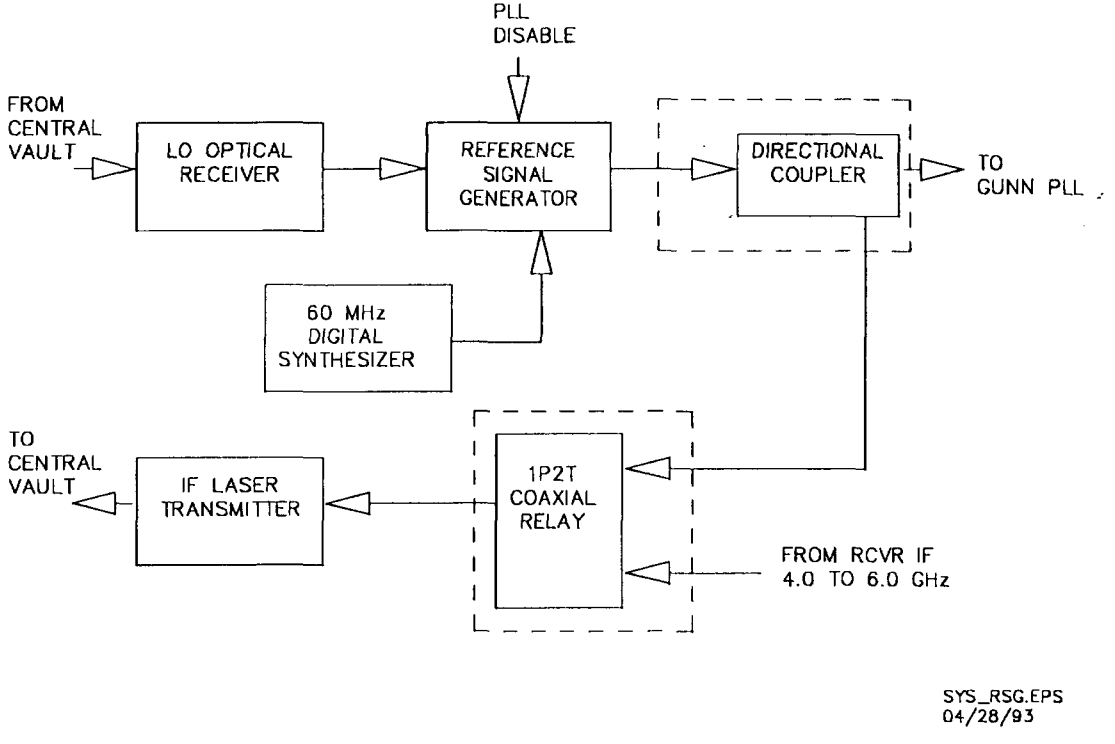

Figure 2 SMA REFERENCE SIGNAL GENERATOR - BIT MODIFICATIONS

3.2 IF Coherent Test Mode

The coherent test mode needs an extended Master Reference Generator, in addition to the parts required to configure the open-loop test capability. The revised MRG is shown in Figure 3; only one of the two units is shown. Again, dotted lines enclose the items specifically added for IF test purposes. No additional hardware is required for the limited-range coherent test mode.

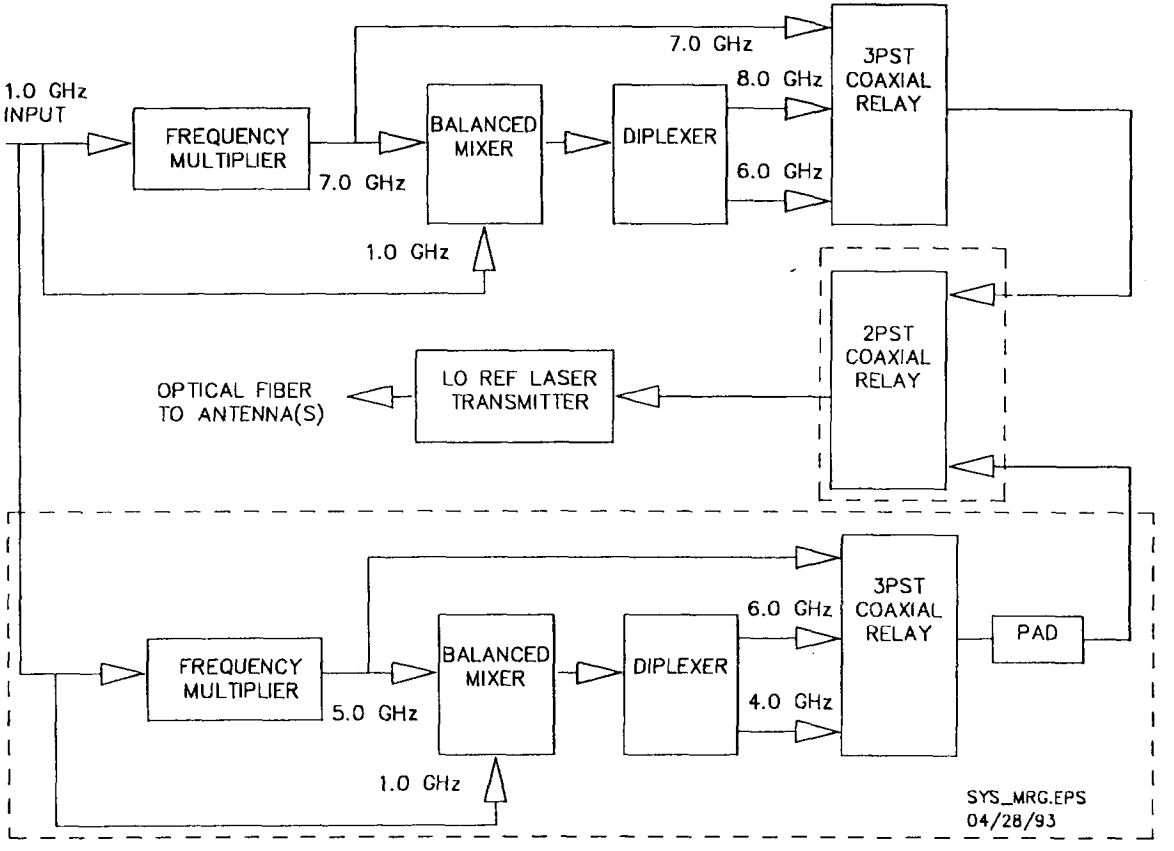

Figure 3 SMA MASTER REFERENCE GENERATOR - BIT MODIFICATIONS