ADDITIONAL BASELINE TO INTERFEROMETER
MEMO No. 162

NATIONAL RADIO ASTRONOMY OBSERVATORY
Green Bank, West Virginia

NEW MICROWAVE LINKS FOR THE NRAO INTERFEROMETER

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February 2, 1982

General Requirements

The microwave links between the interferometer control building and the remote sites must provide phase stable local oscillator signals at each of the remote antennas and transmit the two 30 MHz wide radiometer outputs to the control building. Provisions are also required to transmit the information required to monitor and control the antennas. The new links must interface readily to existing equipment. Also, operation in the 16.2 to 18 GHz frequency range is desired to avoid interference with astronomical observations at Green Bank.

Microwave Link Paths

The Green Bank to Monterville and Green Bank to Huntersville link paths are shown in Figure 1. The passive reflectors are required in both paths to provide adequate path clearance. At 17.5 GHz the Green Bank to Huntersville path loss with 6-ft parabolic antennas and a single 10 ft x 16 ft reflector should be 65 dB. The path from Green Bank to Monterville has three 10 ft x 16 ft passive reflectors and has a calculated path loss of 70 dB with 10 ft parabolic antennas at each end.

Local Oscillator Phase Control Design Requirements

The system will be designed to keep the phase errors between the control building master oscillator and the remote 1347.5 MHz oscillator under 1 degree RMS.

Basic System

To implement the phase control the basic design shown in Figure 2 will be used. The remote oscillator signal $\omega_L/2$ is transmitted through a path with time delay, T_A, to the control building and mixed with signal ω_L. The difference frequency ω_L is transmitted back to the remote site through a path with delay T_B. If the changes in the delay in the up and down link paths are made to be equal, then the phase of the ω_L signal at the remote site is stable with respect to the control building oscillator. This design eliminates the need for servo control phase shifters. The system does have two problems. The isolation of the mixer at the control building must be greater than 50 dB to prevent the incoming $\omega_L/2$ signal from leaking through and causing significant phase changes in the outgoing $\omega_L/2$ signal. Also, at the remote antennas a common cable is used to carry the $\omega_L/2$ signals in both directions. Even small reflections in the cable could cause large phase errors.

Frequency Offset

To overcome these problems an offset oscillator will be used as shown in Figure 3. The incoming signal $\omega_L/2$ is mixed with the output of a voltage controlled oscillator operating at $\omega_L/2 - \omega_0$. The difference frequency, ω_0, is compared with the offset oscillator in the phase detector. The output from the phase detector controls the $(\omega_L/2 - \omega_0)$ oscillator. This signal is mixed with the control building oscillator ω_L and the difference frequency $\omega_L/2 + \omega_0$ and the offset frequency ω_0 are transmitted to the remote station. At the remote station the signals are recombined to generate ω_L. The phase stability of this signal is dependent upon equal changes in delay of paths T_A, T_B, and T_C and also upon the offset frequency.

Microwave Link Implementation

To implement the phase control through a microwave link the design shown in Figures 4 and 5 will be used. The 17.5 GHz carrier is used to transmit the radiometer outputs, environmental monitors, and the digital data from the remote stations to the control building.

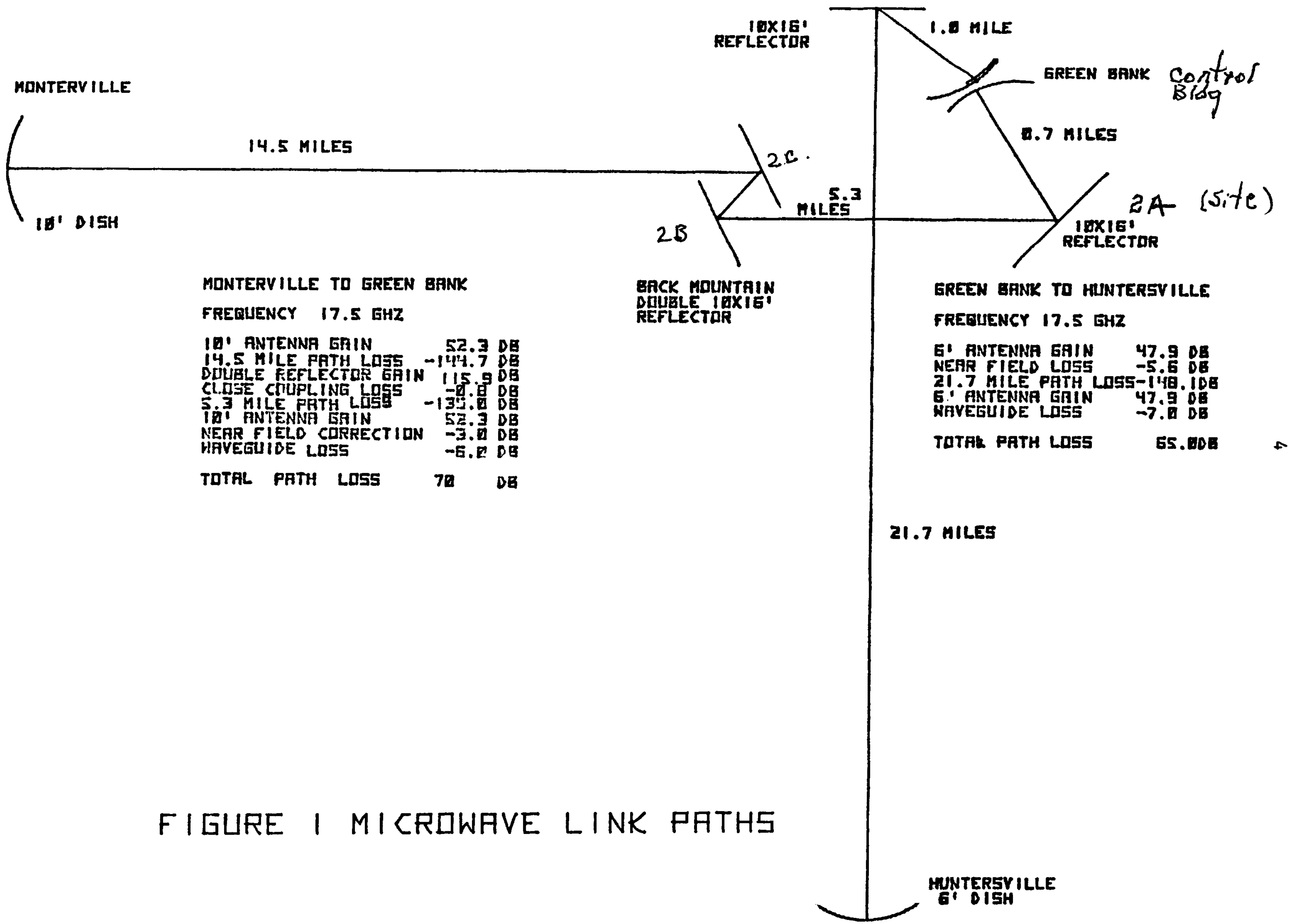
The 17 GHz carrier transmits the local oscillator signals to and from the remote antennas on a time shared basis. For 25 millisec the signals are transmitted from the control building to the remote stations. The next 24 millisec signals are transmitted from the remote station to the control building. By using the same carrier frequency in both directions the down and back path delay changes should be identical.

Link Local Oscillator Signals

As shown on Figure 5, Remote Station Link System, the 96.25 MHz signal is the amplified output of the Voltage Controlled Crystal Oscillator. This signal is sent from the front-end box at the antenna focal point to the equipment trailer through the antenna cable. It is mixed with the 17 GHz oscillator output. This double side-band amplitude-modulated signal is amplified and transmitted from the antenna. At the remote station the transmit receive, T/R, control signal will turn the 17 GHz oscillator output on for a period of 24 millisecs starting when the 17 GHz signal from the control building goes off.

On Figure 4, Control Building Link System, the 17.0 GHz modulated carrier is received by the antenna and routed to the diplexer by the circulator. The diplexer separates the 17.0 GHz signals from the 17.5 GHz modulated carrier. A 17.4 GHz oscillator is used to down convert both the 17.0 and 17.5 GHz carriers to IF frequencies where amplification and detection can more easily be accomplished. The recovered 96.25 MHz signal and the 100 kHz oscillator are used to phase lock the offset 96.15 MHz VCXO. This signal mixes with the 192.5 MHz output from a voltage controlled crystal oscillator that is derived from the master oscillator 1317.5 MHz and 30 MHz signals. The resulting 96.35 MHz signal, the digital data subcarrier and the 100 kHz subcarrier modulate the control building 17 GHz oscillator. The output drives the power amplifier and is transmitted to the remote station.

On Figure 5 again, the 17 GHz signal from the antenna goes through the circulator and filter and is mixed with 17.5 GHz. The IF signal is amplified and envelope detected to recover the 96.35 MHz signal and also the 100 kHz offset oscillator signal. These signals are routed back up the antenna cable to the front-end box. The 96.35 MHz signal is mixed with the 96.25 MHz signal to give an output of 192.6 MHz. This signal is mixed with a 192.5 MHz signal which is derived from the power amplifier output of 1347.5 MHz and the 1155 MHz output from the comb generator. This should eliminate phase errors introduced by the comb generator or the power amplifier. The 100 kHz output is compared with the 100 kHz signal sent from the control building and this output controls the phase of the 96.25 MHz VCXO. The remote station 1347.5 MHz output should be phase stable with respect to the control building master oscillator signals.



MONTERVILLE TO GREEN BANK

FREQUENCY 17.5 GHZ

10' ANTENNA GAIN	52.3	DB
14.5 MILE PATH LOSS	-144.7	DB
DOUBLE REFLECTOR GAIN	115.9	DB
CLOSE COUPLING LOSS	-0.8	DB
5.3 MILE PATH LOSS	-135.0	DB
10' ANTENNA GAIN	52.3	DB
NEAR FIELD CORRECTION	-3.0	DB
WAVEGUIDE LOSS	-6.0	DB
TOTAL PATH LOSS	70	DB

GREEN BANK TO HUNTERSVILLE

FREQUENCY 17.5 GHZ

6' ANTENNA GAIN	47.9	DB
NEAR FIELD LOSS	-5.6	DB
21.7 MILE PATH LOSS	-148.1	DB
6' ANTENNA GAIN	47.9	DB
WAVEGUIDE LOSS	-7.0	DB
TOTAL PATH LOSS	65.0	DB

FIGURE 1 MICROWAVE LINK PATHS

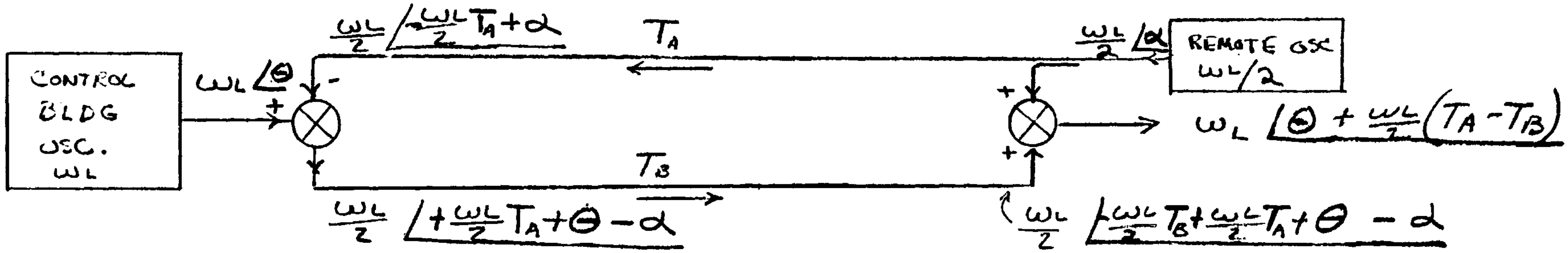


FIGURE 2: BASIC PHASE CONTROL SYSTEM

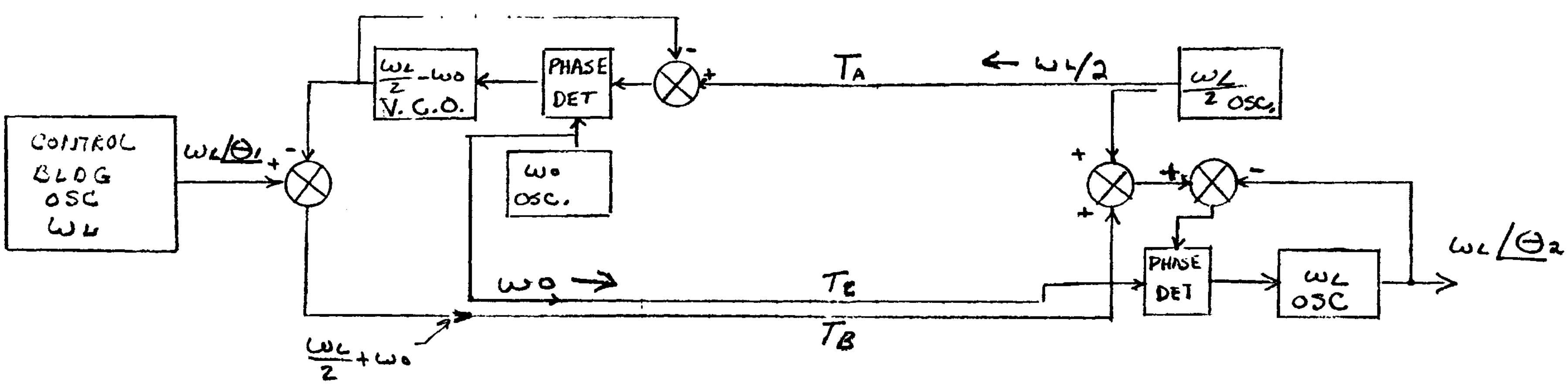


FIGURE 3: OFFSET OSCILLATOR PHASE CONTROL SYSTEM

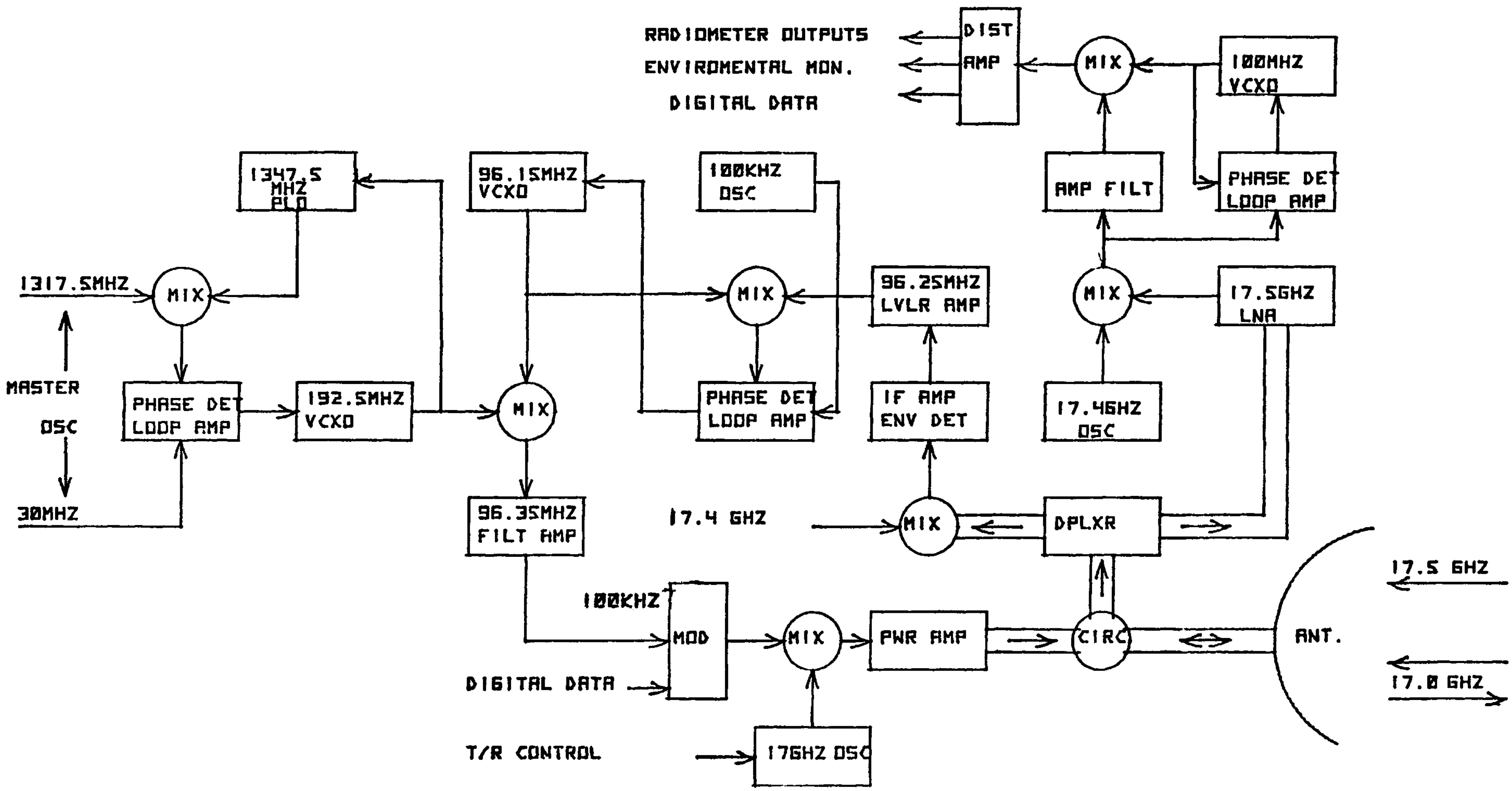


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FIG. 4 CONTROL BLDG LINK SYSTEM

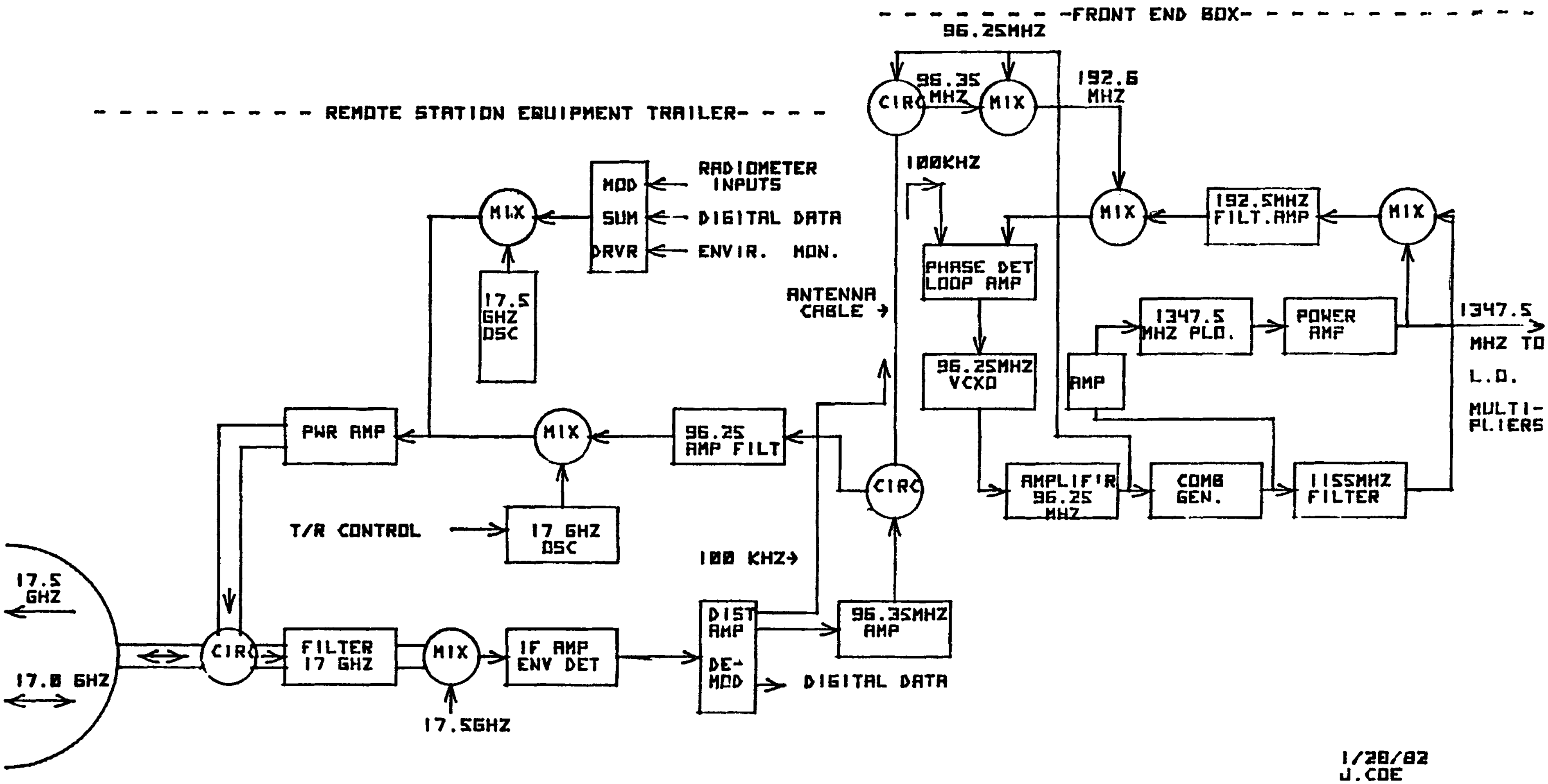

FIG.5 REMOTE STATION LINK SYSTEM