Interoffice

National Radio Astronomy Observatory

Green Bank, West Virginia

To: IG File

July 26, 1966
IG 030 66

From: K. H. Wesseling

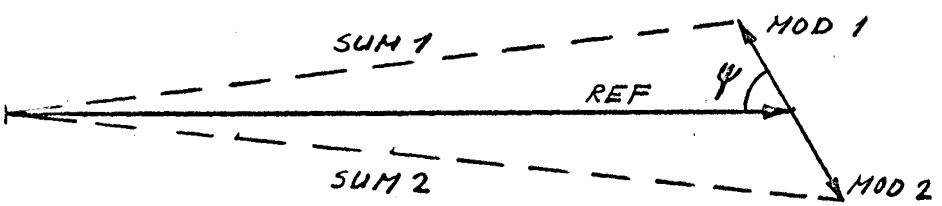
Subject: Instrument to Measure Cable Electrical Length

Introduction

During the last two weeks R. Ervine and the undersigned put an instrument together to measure the electrical, or phase, length of 50 ohm coaxial cable. The apparatus is built following the "Swarup and Yang" or "modulated termination" principle (IRE Trans., AP-9, No. 1, Jan. 1961, pp. 75-81; Benelux Cross Antenna Project ITR 39-66). The method is mentioned as item No. 4 in a previous memo (IG 027 66).

Principle

The main blocks in the instrument are a signal generator that sends a highly frequency stable signal down the cable to be measured, a modulated termination at the other end of the cable which gives 180° phase modulation in the reflected wave at a 400 Hz rate, and detection equipment on the sending end of the line. The transmitted unmodulated wave is called "reference"; the modulated reflected wave is called "modulation". At the detection point both waves interfere. The following phasor diagram can be made.



The detector output voltage represents the sum phasor 1 during one-half of the time, sum 2 during the other half, giving a DC output plus 400 Hz modulation.

The modulation is amplified in an audio amplifier and synchronously detected. A null in the synchronous detector output indicates zero modulation of the detector output. Such a null is obtained if both sum phasors have equal length or if both mod. 1 and mod. 2 are of equal strength and $\psi = 90°$. This occurs every $\lambda/4$ along the cable. If an initial null is obtained, and the cable changes its length by Δl, then the output from the synchronous detector will be proportional to sin $2\Delta l$. This output is recorded.

Calibration

Calibration is done by giving the cable a known length variation by means of a line stretcher. The deflection on the recorder is noted and marked in "mm cable". Another possibility is to put a line stretcher in the reference channel (see block diagram) and mark the deflection as "mm ref". The 1 mm cable corresponds to 2 mm ref. This last method is used. Since the recorder deflection is dependent upon the attenuation of the cable, a new calibration must be made for each cable to be measured.

Sensitivity

A peak-to-peak noise variation of less than 0.01 mm cable is observed under the following circumstances:

Transmitter power ----------	1 mW
Receiver noise temperature ---	2500 °K
Time constant ----------	10 s.
One way cable att. ----------	30 dB

Ultimate Sensitivity

A maximum one-way cable loss of approximately 50 dB can be tolerated under the following conditions:

Transmitter power ----------	Higher
Receiver noise temperature (noise optimized balanced mixer-preamp) ----	600 °K
Time constant (maximum value on NRAO synchronous det.)--	30 s.
Peak-to-peak noise ----------	1 mm cable.

Stability

The temperature coefficient of the modulated termination was measured by varying the temperature of the termination while keeping the rest of the equipment at constant temperature. Over a 40 °C range the temperature coefficient is 0.025 mm cable/°C.

Switch current variations to the modulated termination of ± 20%, symmetrical or to one side only, gave variations less than 0.05 mm cable. The temperature coefficient of the equipment including the switch is less than 0.05 mm cable/°C.

Program

P. Honsberger will use the equipment to measure various cables and reciprocal components in the NRAO interferometer LO distribution system.

KHW/cjd

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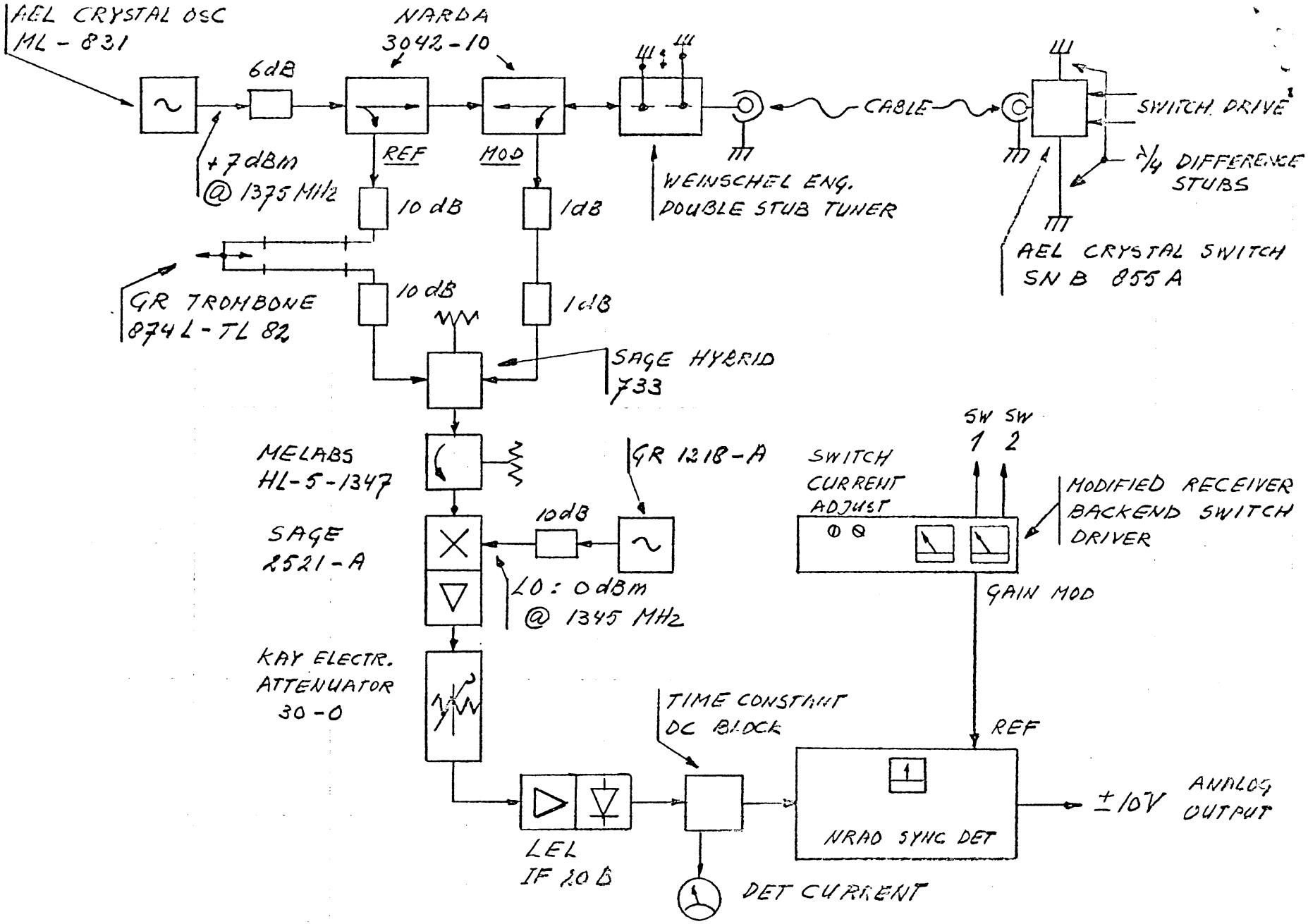

BLOCK DIAGRAM SWARUP + YANG TYPE CABLE-LENGTH-METER

24 JULY 1966

K.H. WESSELING