STADAN ANTENNA GAIN CALIBRATION USING RADIO STARS

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An antenna gain measurement method has been developed that utilizes a signal emitted from a radio star, such as Cassiopeia A or Cygnus A, to determine absolute antenna gain at 136 MHz and 400 MHz for antennas in the STADAN network. The standard technique is to use an aircraft to determine the gain of STADAN antennas. Antenna gain determinations made with an aircraft reference the measured antenna gain to a standard-gain antenna. Uncertainties in the gain of the standard antenna, system calibration errors, polarization errors, and parallax errors make the aircraft method generally less accurate than the radio-star approach.

As far as station antenna gain measurements are concerned, the adoption of the radio-star method by the stations would eliminate the necessity for a NASA aircraft to visit the stations to make gain measurements. Furthermore, a radio-star gain determination then could be made by site personnel at any time, in a matter of minutes, whereas up to several hours of flying time over the site is required for the aircraft method. A series of over 60 STADAN antenna gain calibrations have been completed over the past year, and each station's antenna gain was measured using both the radio-star and aircraft methods.

In order to make an antenna gain measurement with a radio star, the only special equipment required is an inexpensive square-law diode detector "black box" connected at the intermediate-frequency output from a station receiver (Figure 1). The addition of this "black box" converts the station's RF receiving system into a total power receiver like that used in radio astronomy applications. To determine a station's antenna gain by means of a radio star such as Cassiopeia A, it is only necessary to make two dc voltage measurements at the output of the square-law detector/filter network. These two simple measurements consist of an off-star voltage reading, which includes the contribution of the star's background sky temperature, and an on-star voltage reading which is made with the peak of the antenna's main lobe pointing directly at the radio star (Figure 1). A necessary condition for the off-star reading is that the antenna's axis be rotated to position the radio star in the first null of the antenna's radiation pattern; however, since the radio star is essentially a point source, this poses no problem.

An error analysis of the radio-star gain determination method for the radio stars and antennas considered here shows that the overall standard deviation uncertainty in antenna gain is only ±0.6 dB (1 σ). At 136 MHz, using Cassiopeia A, the mean values and 1-σ uncertainties in the parameters influencing the overall gain uncertainty include a background sky temperature of 900 ± 100 K, obtained from a radio map; a flux density of $(13.8 \pm 1.1) \times 10^{-23}$ W-m^{-2}-Hz^{-1} for Cassiopeia A; a 1-σ error of ±10 percent in the voltage measurements obtained from the square-law detector; and other uncertainties in the various parameters used in the expression for effective antenna gain (Figure 1).

The series of over 60 antenna gain calibrations recently completed at the stations, verifies that the square-law detector output voltage 1-σ error is indeed within the allowable limits of ±10 percent. (A number of detector voltage measurements were averaged to determine the standard deviation for a given gain calibration.)

The representative antenna gain determinations shown in Table 1, obtained from the series of over 60 determinations made using a radio star, reveal that the overall standard deviation uncertainty in effective antenna gain is close to ±0.6 dB. In each case, the uncertainty in each radio-star gain determination was computed using the specific detector voltage measurement error for that determination. The values of 1-σ quoted in Table 1 also reflect uncertainties in the other parameters influencing effective antenna gain at both 136 MHz and 400 MHz.

The ±1.5 dB uncertainty in the corresponding aircraft gain determinations is admittedly heuristic but is, nevertheless, based upon discussions with personnel who made the aircraft measurements. This uncertainty includes the influence of the various error sources, mentioned earlier for the aircraft method.

It should be recognized that both the radio-star and aircraft gain determinations were made at the stations by an independent group under the supervision of GSFC personnel.

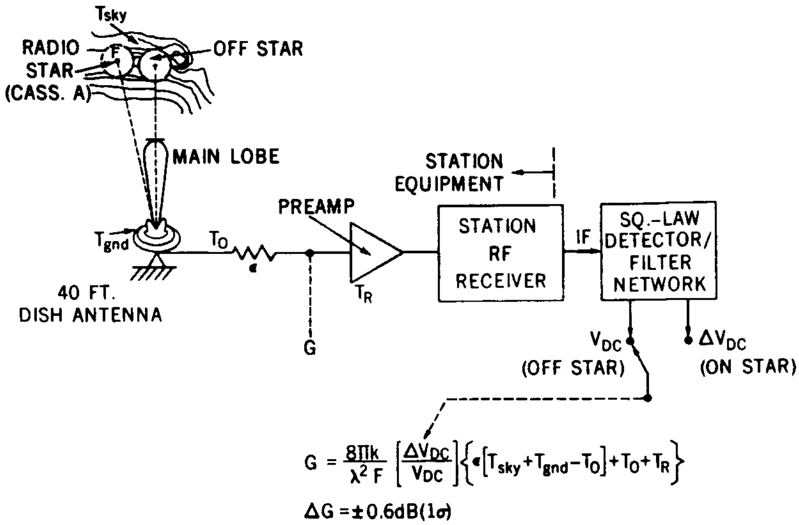

Figure 1—Antenna gain calibration using radio star.

Table 1—Antenna gain measurements.

STADAN STATION	TYPE ANTENNA	FREQ (MHz)	G EFFECTIVE ANTENNA GAIN STAR (db ± 1σ)	G EFFECTIVE ANTENNA GAIN AIRCRAFT (db ± 1σ)
QUITO	SATAN	136	19.3 ± .59	19.9 ± 1.5
QUITO	40' DISH	136	16.9 ± .61	16.0 ± 1.5
SANTIAGO	SATAN	136	20.7 ± .59	21.0 ± 1.5
ALASKA	SATAN	136	20.8 ± .68	20.6 ± 1.5
MADAGASCAR	SATAN	136	20.3 ± .47	20.1 ± 1.5
MADAGASCAR	40' DISH	400	29.9 ± .47	30.4 ± 1.5
JOBURG	40' DISH	400	29.7 ± .59	28.7 ± 1.5