High Power Amplifier Harmonic Output Level Measurement*

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Abstract

A method is presented for the measurement of the harmonic output power of high power klystron amplifiers, involving coherent hemispherical radiation pattern measurements of the radiated klystron output. Results are discussed for operation in saturated and unsaturated conditions, and with a waveguide harmonic filter included.

1 Introduction

The Deep Space Network, managed by the Jet Propulsion Laboratory, uses high power CW klystron amplifiers for spacecraft communication. The power radiated by a transmitter at harmonics of the fundamental frequency can interfere with other users, dictating the inclusion of harmonic-reject filters between the klystron amplifier and the feedhorn. Identifying the power level produced by the klystron at each harmonic frequency is thus important in the design of harmonic-reject filters.

2 Measurement Method

The measurement of harmonic output power is complicated by the large number of propagating modes possible in the rectangular output waveguide system, particularly at the higher harmonics. Methods using mode-selective couplers or probes, Refs. [1-3], were rejected due to the number of components required to sample each mode of propagation, the difficulty in calibrating the measured power to an absolute standard, and the possibility of extraneous mode conversion introduced by the measurement system itself.

*This work was performed at the Jet Propulsion Laboratory, California Institute of Technology under a contract with the National Aeronautics and Space Administration.

The harmonic measurement method chosen consists of making a hemispherical radiation pattern measurement of the transmitter output feedhorn at each harmonic frequency of interest. By integrating over the radiation pattern, and scaling against a calibration signal the total power radiated by the klystron transmitter at each harmonic frequency was obtained.

The Deep Space Network operates transmitters at both 2.1 GHz and 7.2 GHz. It was decided to perform these measurements on a 2.1 GHz 20 kW CW transmitter to eliminate the mechanical alignment difficulties of performing multiple radiation pattern measurements at millimeter wave frequencies, as a measurement up to the fourth (4Fc) harmonic was desired. Additionally, a simple straight waveguide run containing no bends between the klystron (Varian 5K70SG) and feedhorn was used to minimize mode mixing. .

A system was designed (Fig. 1) to perform the hemispherical radiation pattern measurement through successive radial radiation pattern measurements using a receiving antenna (standard-gain rectangular waveguide feedhorn). Since the polarization of each radiated modal component at a given harmonic was unknown, a second hemispherical pattern measurement was required with the receiving antenna rotated by 90 degrees.

The RF system (Fig. 2) enabled amplitude and phase measurements to be made coherently for each harmonic of interest. A comb generator driven at a subharmonic (528.75 MHz) of the transmitter carrier frequency to provide the required reference frequency at each harmonic, as well as the 2.1 GHz signal to excite the transmitter.

Calibration of the system at each harmonic frequency was accomplished by rotating the receiving feedhorn at zenith, and placing a second identical feedhorn coaxial to the transmitter output feed. A reference power level at the frequency of interest was then injected into the calibration feed, and the amplitude indication of the measurement system noted.

Each radial radiation pattern consisted of 180 data points with one degree increment. Hemispherical coverage was then obtained by rotating the scan arm in azimuth in 15 degree increments.

3 Results

As a check of the method, the initial measurements were performed using a 4.2 GHz standard gain horn at 44.3 mW radiated power. After calibration, measurement and integration a total power of 45.5 mW was obtained, resulting in a 2.2% error.

Measurements using the klystron transmitter were made at 4.2, 6.3 and 8.4 GHz. At each frequency, the amplifier was operated saturated (20 kW output power) and below saturation (15 kW) and saturated with a 4.2 GHz notch filter installed. The results may be found in Table 1.

As expected, in all cases the harmonic output level was higher in saturated operation of the klystron. In both saturated and unsaturated cases, the third harmonic (6.3 GHz) exhibited the lowest level of the harmonics tested. The waveguide notch filter exhibited an insertion loss of 57.5 dB at 4.2 GHz, close to its specified value of 60 dB attenuation. The higher harmonics were also substantially attenuated by the filter.

4 Conclusion

An accurate and versatile method for measuring the harmonic output of high power amplifiers was presented. The method eliminates many of the problems associated with other techniques for measuring the harmonic output of high power amplifiers. Measurements of a representative klystron were discussed. Results obtained were consistent with expectations.

References

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[2] J. J. Taub, "A New Technique for Multimode Power Measurement", *IRE Transactions on Microwave Theory and Techniques*, vol. 10 , no. 11, pp. 496-505, Nov. 1962.

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Frequency	Saturated (no filter)	Unsaturated (no filter)	Saturated (filter)
4.230 GHz	-33.3 dBc	-34.8 dBc	-90.8 dBc
6.345 GHz	-47.8 dBc	-52.5 dBc	< -91.4 dBc
8.460 GHz	-42.7 dBc	-51.4 dBc	-88.5 dBc

Table 1: Harmonic power output levels for various operating conditions

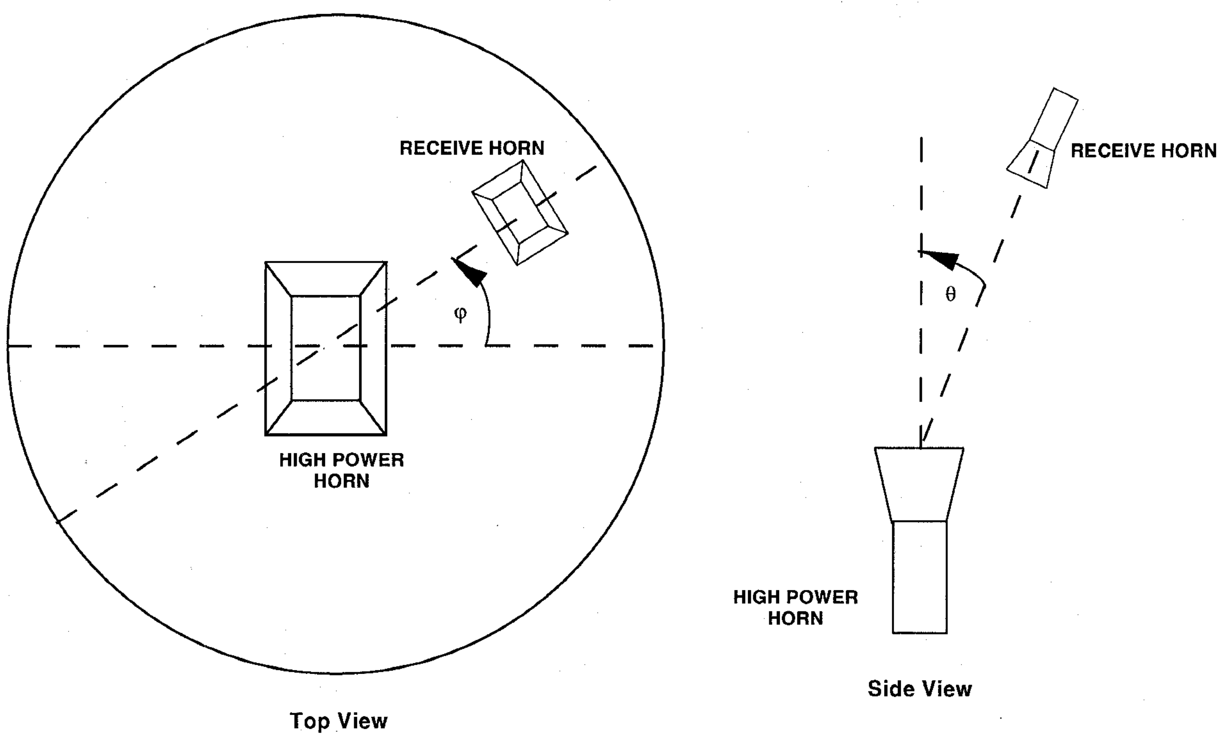

Figure 1: Radiation pattern measurement system.

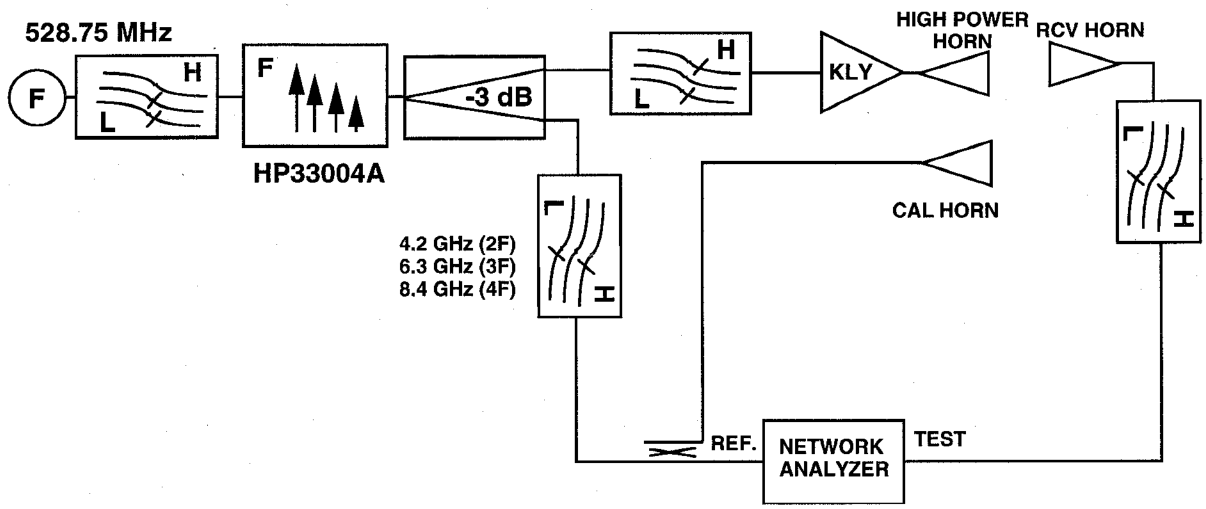

Figure 2: Amplitude and phase measurement system.