

TECHNIQUE FOR DETERMINING THE POWER FLUX DENSITY OF INTERFERING SIGNALS AT TELEMETRY RECEIVING STATIONS

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ABSTRACT

This paper will present techniques for accurately measuring the power flux density (PFD) of interfering signals at telemetry receiving stations. The solar power flux density is measured daily by radio astronomers and will be used as a calibration signal. The electromagnetic spectrum is being used more intensely as time marches on so being familiar with interference measurement techniques is becoming more important because more interfering signals are present.

KEY WORDS

Telemetry, power flux density, interfering signal levels, interference, solar flux density

INTRODUCTION

This paper presents a method for determining the power flux density (PFD) of an interfering signal at a telemetry receiving site by comparing measured power levels from the sun and the interferer. The PFD of the sun is measured daily at several frequencies by several solar observatories and therefore provides a calibrated reference¹. The interferer PFD measurements are made by pointing the telemetry receiving antenna at the interfering signal's source. The measurements can be made across the frequency range of interest using a spectrum analyzer. Probably the biggest problem with using a spectrum analyzer is that typical spectrum analyzers have noise figures of 30 dB or higher. Therefore, an extra preamplifier may be needed to

¹ Hedeman, W. R., "The Sun as a Calibration Signal Source for L- and S-band Telemetry", Proceedings of the 1968 International Telemetry Conference, page 330

minimize spectrum analyzer noise contributions. This test also determines the figure of merit (gain/temperature (G/T)) of the receiving antenna system. The G/T is the ratio of the antenna gain to the system noise temperature.

MEASUREMENTS

This paper will use measurements at the Makaha Ridge telemetry receiving facility of the Pacific Missile Range Facility (PMRF) on May 16 and 17, 2005 as measurement examples. The purpose of these measurements was to determine the potential effect of XM Satellite Radio, hereafter referred to as XM, and Sirius Satellite Radio, hereafter referred to as Sirius, signals on telemetry reception at PMRF. XM and Sirius provide satellite digital radio service to the 48 contiguous states in the 2320-2345 MHz band. They do not currently provide service to Hawaii. XM currently has 3 satellites in geosynchronous orbit and Sirius has 3 satellites in highly elliptical orbits. The visible XM satellite was at an elevation angle of 34 degrees and an azimuth angle of 111 degrees. Both Sirius 1 and Sirius 3 were visible during the test intervals and measurements were made of both satellites. The Sirius satellites were at elevation angles of 23 to 43 degrees and azimuth angles of 28 to 109 degrees during the measurement times. The telemetry antenna used for these examples was a 20-foot diameter antenna (150-20-1). The measurements were made using a spectrum analyzer with a 300 kHz resolution bandwidth and a 30 Hz video bandwidth at frequencies of 225 –275 MHz (which is equivalent to input frequencies of 2310-2360 MHz because the input frequencies are shifted down by 2085 MHz in the downconverter). A block diagram of the measurement system is shown in figure 1. The measurement process consisted of pointing the antenna at the satellite, sun or cold sky (the antenna was then placed in autotrack mode for the satellites and the sun) and measuring the spectral energy in both left-hand circular (LHC) and right-hand circular (RHC) polarizations. The sun measurements allow one to calculate the system G/T and compare with previously measured values and also to calculate the satellite power flux densities (PFDs). The measured system G/T values were about 16 dB/K for the 20-foot antenna. The spectrum analyzer accuracy is about 1 dB and this value is within 1 dB of the expected value. One could calculate the expected interference level of any other antenna at this approximate location if one knows the G/T of the antenna by first subtracting the G/T of this antenna from the interference levels measured with this antenna and then adding the G/T of the new antenna.

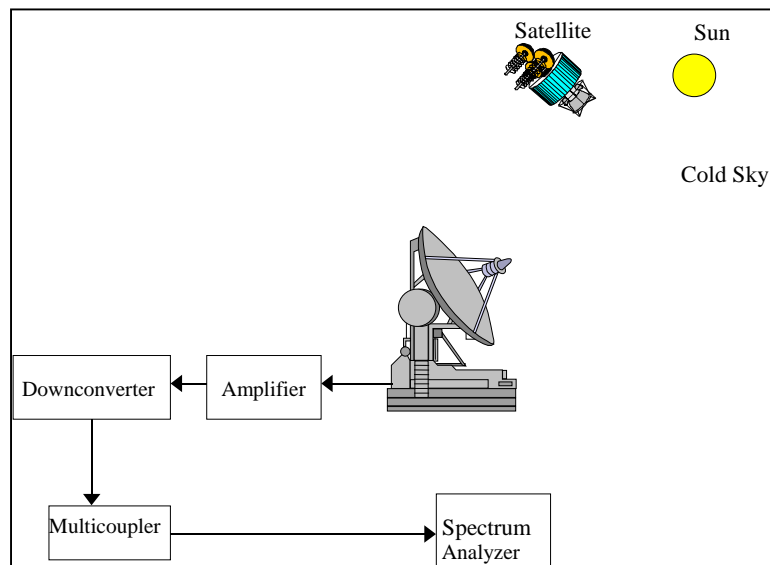


Figure 1. Measurement block diagram.

First, point the antenna at the interfering signal source (satellites for this example). Measure and record the received power over the frequency range of interest for both LHC and RHC polarizations. Point the antenna at the Sun and track the Sun (the Sun should be at least several beamwidths away from the satellite to minimize interference between the sources). Measure and record the received power over the frequency range of interest for both LHC and RHC polarizations. Point the antenna at the cold sky (at least several beamwidths away from both the satellite and the Sun). Measure and record the received power over the frequency range of interest for both LHC and RHC polarizations. The increase in the (interference + noise) floor caused by pointing the antennas directly at the satellites can be calculated by subtracting the measured sky values from the satellite values at each frequency. Figure 3 shows these results for the 20-foot diameter antenna. The first part of the legend indicates which satellite was measured (XM, S1, S3, or SUN), the second part is the elevation angle in degrees, the third part is the azimuth angle in degrees, and the fourth part is the polarization (L for LHC and R for RHC). Note that all of the satellites measured had most of their energy in LHC while the Sun was nearly balanced between LHC and RHC. If one points a few degrees away from the satellite the degradation is small. For example, at the first antenna sidelobe peak XM-1 caused only about 5 dB of degradation with the 20 foot antenna. The first sidelobes are about 2.4 degrees away from boresight for the 20 foot antenna.

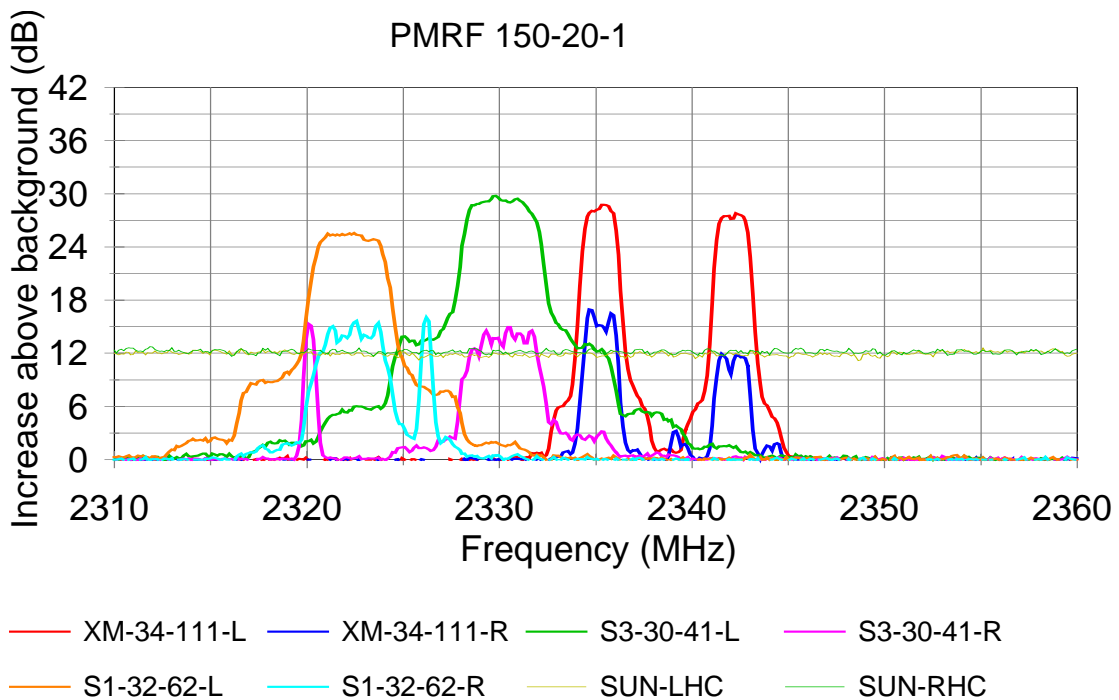


Figure 2. Measured interference levels with PMRF antenna 150-20-1 (values are relative to sky power levels).

CALCULATIONS

One can calculate the satellite PFD for each polarization and frequency using the equation below. The units of the satellite PFD are dBW/meter²/4kHz. The first term in the equation below corrects the solar PFD for the atmospheric absorption and the antenna aperture. The second term finds the ratio of the satellite power and Sun power after subtracting the background sky noise power for each polarization. This ratio (in dB) gives the satellite PFD after converting to a 4 kHz bandwidth (+36 dB) and converting the solar PFD to a single polarization (-3 dB).

$$PFD = 10 \log \left(\frac{S_f}{k_2 L} \right) + 10 \log \left(\frac{P_{sat} - P_{sky}}{P_{sun} - P_{sky}} \right) + 36 - 3$$

Where:

- P_{sat} = satellite power at IF output for a given polarization at a given frequency
- P_{sky} = cold sky power at IF output for a given polarization at a given frequency
- P_{sun} = sun power at IF output for a given polarization at a given frequency
- S_f = power flux density converted to the test frequency
- L = aperture correction factor
- k_2 = Atmospheric attenuation

and

To convert the Sun power flux density measurements into flux densities at the test frequencies, use the equation below². The units of the measured power flux densities are 10⁻²² watts/meter²/Hz; that is, a reported value of 95 would mean 95 x 10⁻²² watts/meter²/Hz.

$$S_f = \left[\frac{S_{1415}}{S_{2695}} \right]^\Gamma * S_{2695}$$

where

$$\Gamma = \frac{\log \frac{f}{2695}}{\log \frac{1415}{2695}}$$

- S_f = corrected power flux density at the test frequency
- S_{2695} = measured power flux density at 2695 MHz (95 for May 16 and 17)
- S_{1415} = measured power flux density at 1415 MHz (51 for May 16 and 17)
- f = test frequency (MHz)

² RCC 118-02 volume 2 published by the RCC Secretariat; available at <http://www.jcte.jcs.mil/RCC/PUBS/pubs.htm> .

Aperture correction depends on the ratio of the angular size of the sun and the 3 dB beamwidth of the antenna. For simultaneous lobing, the following equation applies:

$$L = 1 + 0.38 \left[\frac{\Phi_d}{\Phi_h} \right]^2 \text{ for } \frac{\Phi_d}{\Phi_h} \leq 1$$

where

Φ_d = angle subtended by the sun (approximately 0.53°)
 Φ_h = 3 dB beamwidth of the sum channel

The correction factor for atmospheric attenuation (k_2) is

$$k_2 = 10^{A_g / (10 * \sin(\alpha))}$$

where

A_g = gaseous absorption in the atmosphere in dB. $A_g = 0.035$ dB for S-band,

α = elevation angle

Figure 3 shows the satellite PFDs calculated using the equations above and the measurements from the PMRF 20-foot diameter antenna 150-20-1. Similar PFD values were calculated with other antennas. The maximum satellite PFD values were similar over time but the spectral shapes of the received signals varied somewhat versus time. The PFD values can be used to

PMRF 150-20-1

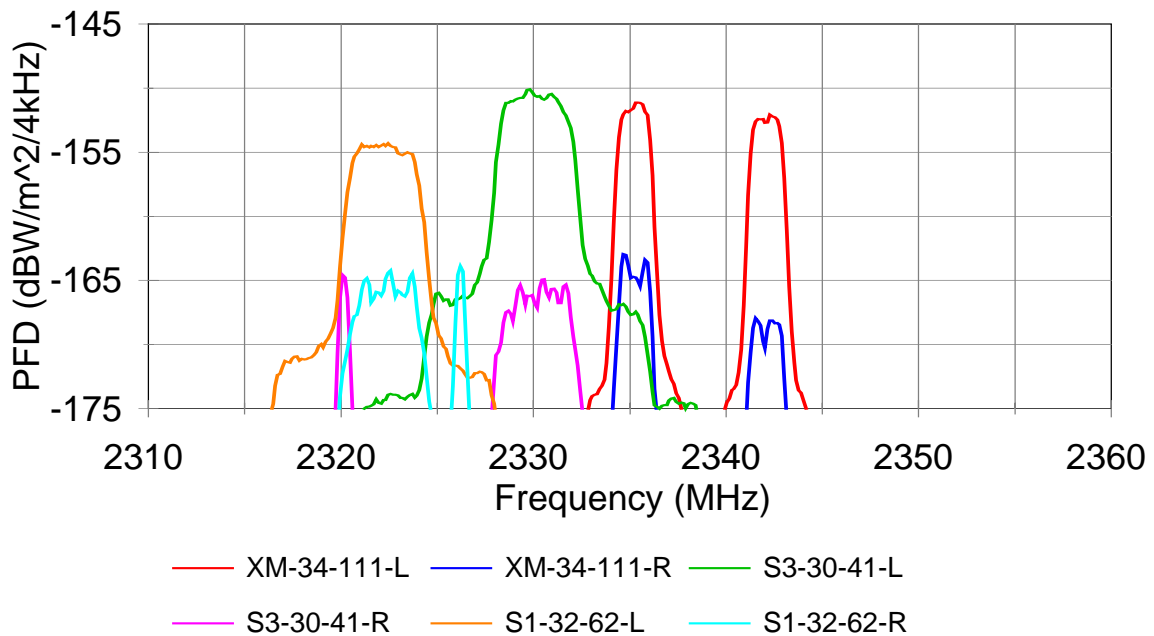


Figure 3. Measured/calculated satellite PFD values for 20-foot antenna at Makaha Ridge.

These satellites can be used to make antenna pattern measurements by “sweeping” the antenna through the satellite location. Figure 4 shows the azimuth scan of antenna 150-20-1 with XM as the signal. The antenna scan rate was 1 degree per second. The frequency was 2335 MHz (2085+250). Note that the sidelobe levels are fairly small.

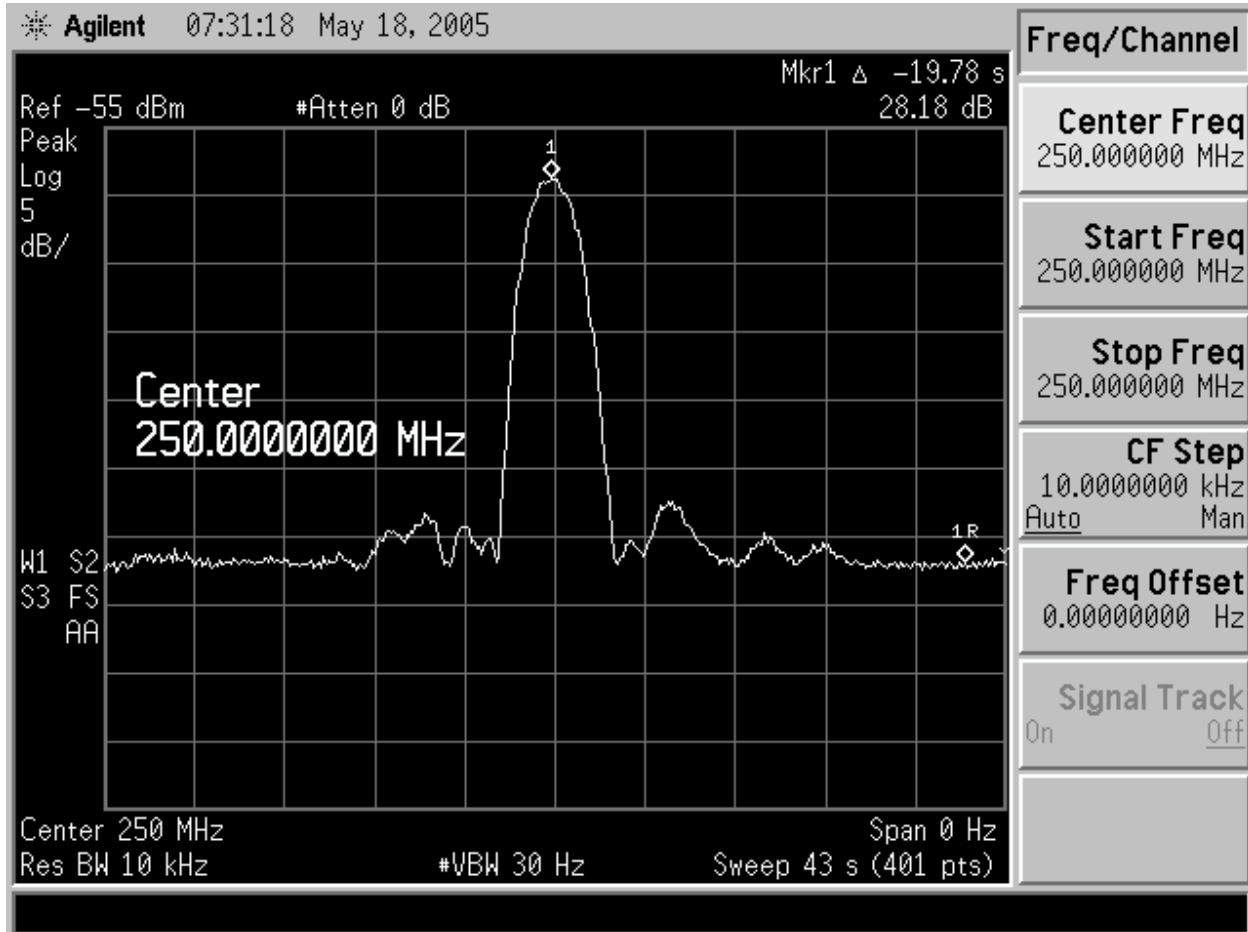


Figure 4. Azimuth antenna pattern of 20-foot antenna performed by sweeping antenna across XM position.

SUMMARY

The tests indicated significant interference at frequencies that the XM or Sirius satellites were transmitting at if the telemetry antenna was pointed directly at the satellite but minimal interference if one was pointed a few degrees away from the satellite. Most of the energy from these satellites was LHC polarized. The interference from Sirius is at frequencies between 2320 and 2332.5 MHz while the interference from XM is at frequencies between 2332.5 and 2345 MHz. A method for measuring the degradation from interfering signals was presented along with a method for calculating the PFD levels of interfering signals.

REFERENCES

1 Hedeman, W. R., "The Sun as a Calibration Signal Source for L- and S-band Telemetry", Proceedings of the 1968 International Telemetry Conference, page 330

2 RCC 118-02 volume 2 published by the RCC Secretariat; available at <http://www.jcte.jcs.mil/RCC/PUBS/pubs.htm>

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