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OLYMPUS PROPAGATION MEASUREMENT RESULTS AT VIRGINIA TECH

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Abstract - Virginia Tech is performing a comprehensive set of propagation measurements using the OLYMPUS satellite beacons at 12.5, 20, and 30 GHz. A second 20 GHz diversity terminal is portable and is moved to various spacings up to 50 m away from the fixed 20 GHz terminal. Total power radiometers are included in each terminal also. Radiometer data are used both to set the absolute level of the beacon data and to predict path attenuation. This paper presents initial results from the experiment set.

1. Introduction

The European Space Agency launched the OLYMPUS satellite in July 1989. In addition to communications experiment packages in Ku- and Ka-bands, OLYMPUS has frequency coherent propagation beacons at 12.5, 19.77 and 29.66 GHz. These beacons are visible from Blacksburg at an elevation angle of 14°. Virginia Tech has four receivers, one at each frequency plus a second portable terminal at 20 GHz for short-baseline diversity measurements.

The receiving system was constructed to take advantage of the frequency coherent beacons. A frequency locked loop derives frequency tracking information from the 12 GHz receiver which experiences smaller fading than that at 20 and 30 GHz. This permits accurate fade measurements of the relatively frequently occurring deep rain fades (25 dB or more) on 20 and 30 GHz. The 12 GHz derived FLL also permits rapid reacquisition after loss of lock.

Measurements at Virginia Tech began in August 1990. Statistical results are currently being processed. These include; fade, fade rate, and fade duration for rain and scintillation events. Frequency scaling results are especially valuable due to the common elevation angle and location of the receivers. Initial results confirm the somewhat less than frequency squared scaling law. For a diversity separation of 50 m for the two 20 GHz receivers, no improvement during rain fading is experienced, while decorrelation for scintillation events is common.

Unfortunately, the OLYMPUS spacecraft lost altitude control on May 29 and has been nonfunctional since. Meanwhile, radiometer measurements continue at Virginia Tech.

These data will be used to characterize propagation conditions on VSAT-type networks for next generation small aperture Ka-band systems.

2. The Measurement System

The propagation experiment system at Virginia Tech continuously records the 12.5, 20, and 30 GHz OLYMPUS beacons using receiving antennas 12, 5, and 4 feet in diameter, respectively. A block diagram of the measurement system is shown in Figure 1.

A unique feature of the OLYMPUS beacon package is that the three spacecraft beacons are coherent since they are derived from a common oscillator. The Virginia Tech OLYMPUS receivers take advantage of their coherence by deriving frequency locking information from the 12.5 receiver. This information is used to maintain lock for all four receivers. In effect, this widens the dynamic range of the 20 and 30 GHz receivers, which experience more fading during a rain event than does the 12.5 GHz receiver.

The receivers at all three frequencies are very similar. Each receiver has a low noise amplifier followed by a mixer-preamp whose output IF frequency is 1120 MHz. A motorized attenuator is included in the RF section to aid in system calibration. The 1120 MHz IF is subsequently mixed down to produce lower IF frequencies of 70 MHz and 10 kHz. The 10 kHz signal is then used in detection and tracking.

A hybrid analog/digital receiver is used in the detection scheme for the 12.5 GHz system. The analog portion of the receiver tracks the carrier frequency and maintains the signal within a 3 Hz window. Simultaneously, the 10 kHz carrier is sampled at a 1 kHz rate by a 12 bit A/D converter. Each sample is then filtered by a digital FIR filter and the resulting 16 bit I and Q values are recorded by the data acquisition system.

Clouds and scintillation can produce up to 3 dB of attenuation at 30 GHz on a 14° elevation-angle path and may be present for a large percentage of the time. Therefore, it is important in a slant-path propagation experiment to be able to set the clear air reference level accurately. Radiometers operate at each beacon frequency in our receiving system to aid in setting this clear air reference level. The radiometers are of the total power design; the RF and IF sections are housed in a temperature controlled environment to keep gain constant. The radiometer design is unique in that it uses the same RF chain as the beacon receiver.

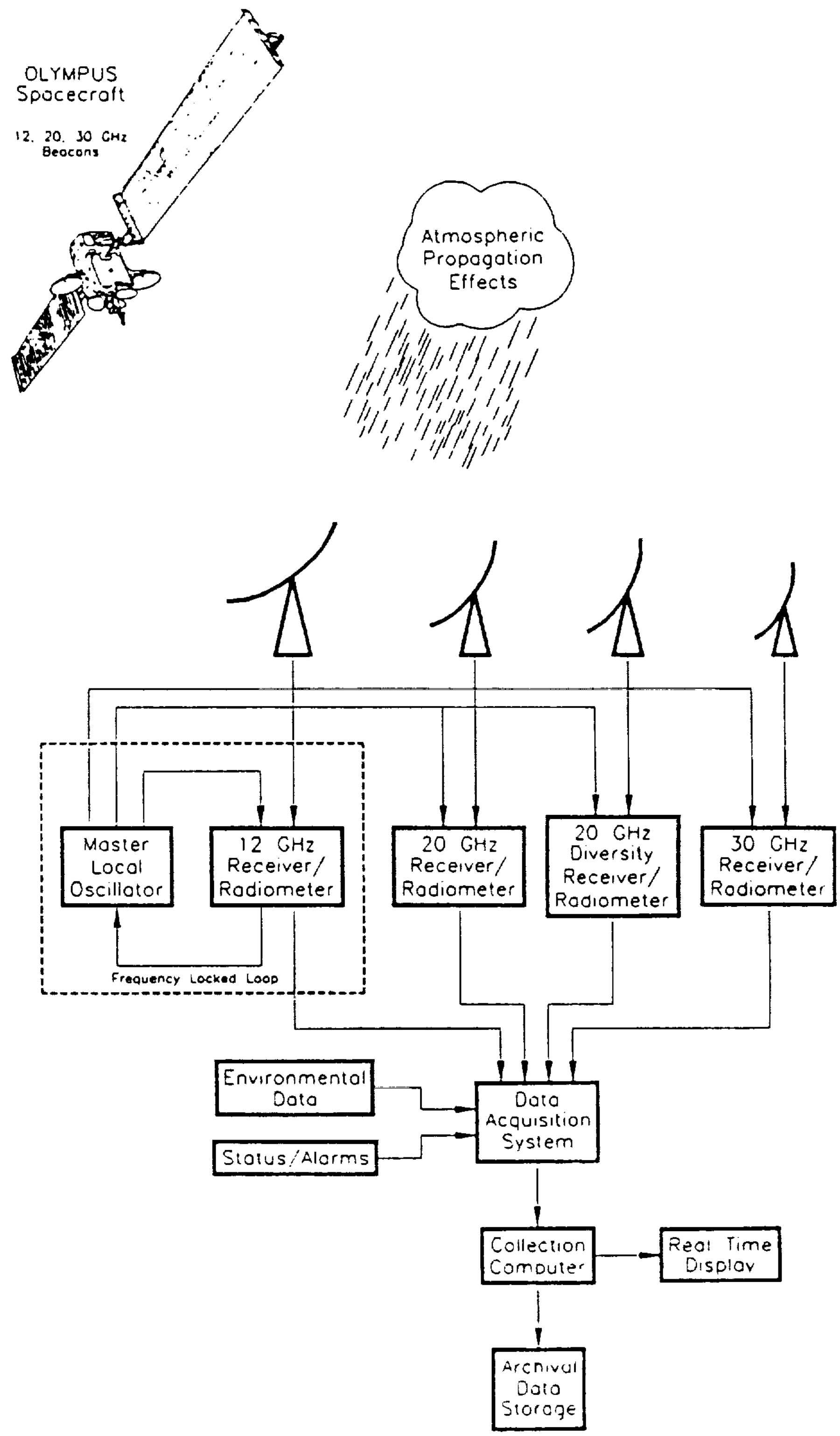

Figure 1. The OLYMPUS measurement system at Blacksburg, VA.

The output of the receivers and radiometers are continuously monitored by a PC-based data acquisition system (DAS). Analysis is performed on a large PC.

3. The Experiment Program

The experiment produces a number of primary and secondary attenuation statistics. Beacon attenuation cumulative distributions referenced both to free space and to clear air are produced. Frequency scaling between frequencies is determined. Secondary statistics such as fade slope, fade duration, and fade interval are also generated.

Radiometer predictions of attenuation are also produced. Small scale diversity as a function of the spacings (and vertical height differences) of the two 20 GHz terminals is examined.

Uplink power control applications are considered as well. Here it is hoped that on a 20/30 link with rain fading on the uplink at 30 GHz the control of the uplink power level (alternatively, coding rate) can be based on beacon measurements at 20 or 30 GHz.

4. Results

Attenuation statistics are being analyzed. Figure 2 shows an example of cumulative distributions for January.

Radiometer data must be accurate to set the beacon reference level, so we examine it first. Radiometer data also take on new significance now that the OLYMPUS beacons are unavailable. Radiometer data have been reduced for the month of January 1991. Radiometer predicted attenuation has an rms deviation of 0.025 dB from directly measured beacon attenuation. This included events with fades as high as 10 dB. Figure 3 shows a scatter plot of radiometric attenuation versus beacon attenuation referenced to free space.

Scintillation events have been analyzed. Preliminary findings show that the spectrum at all frequencies obeys the popular - 8/3 power law. The diversity site (up to 50 m separation) does offer improvement for scintillation events, but not for rain events.

A major use for our data is in uplink power control studies on narrow margin communication links as for Ka-band VSAT application.

We have found that simple scaling laws work very well. They apply to both attenuation and to unnormalized signal levels as would be encountered in practice. For example, predicted attenuation at 30 GHz follows from measured 20 GHz attenuation as

$$A_{30} = a + b\, A_{20} \tag{1}$$

$$\log A_{30} = c + d \log A_{20} \tag{2}$$

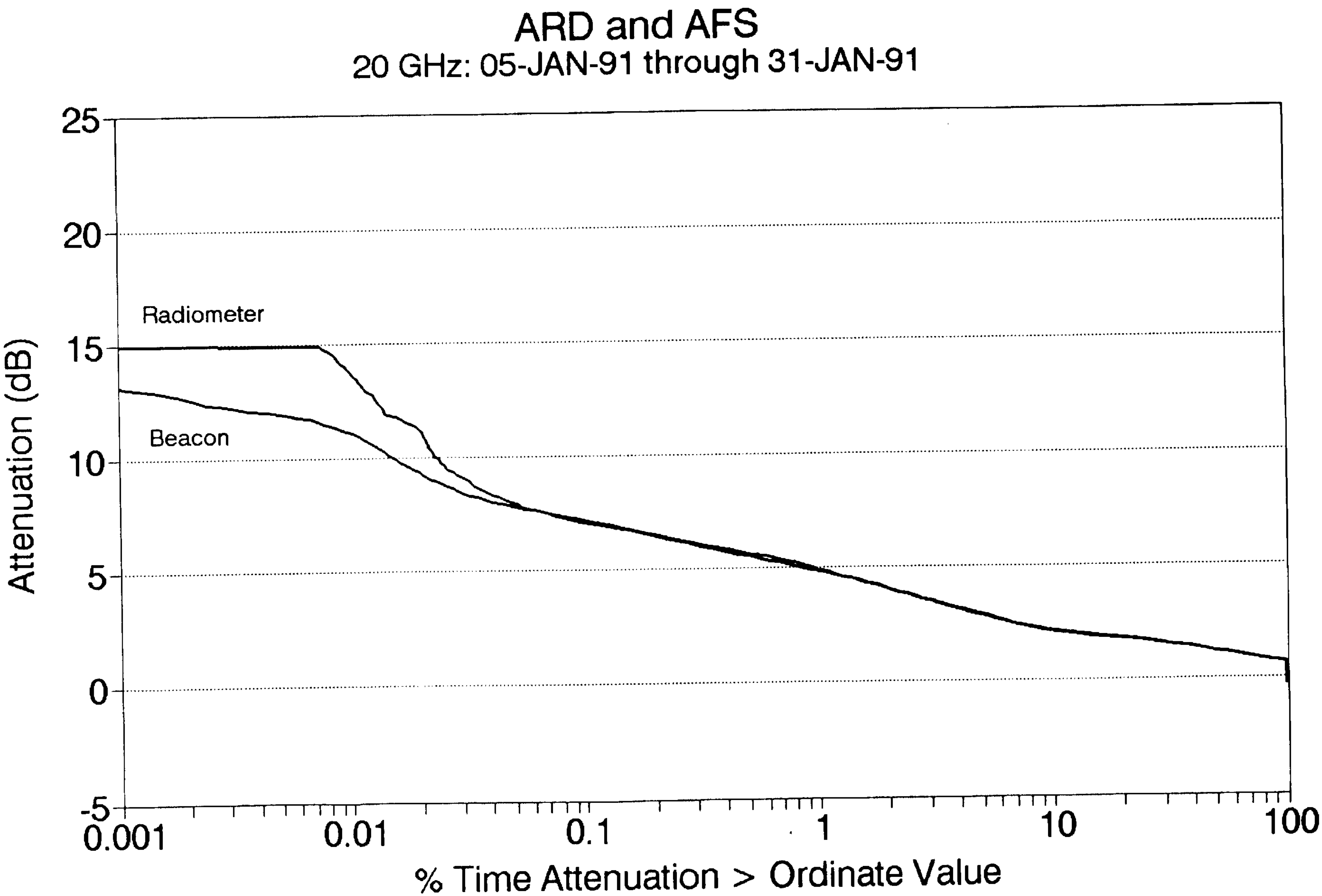

Figure 2. Measured cumulative distributions for January 1991 of beacon attenuation referenced to free space and attenuation predicted from radiometer measurements.

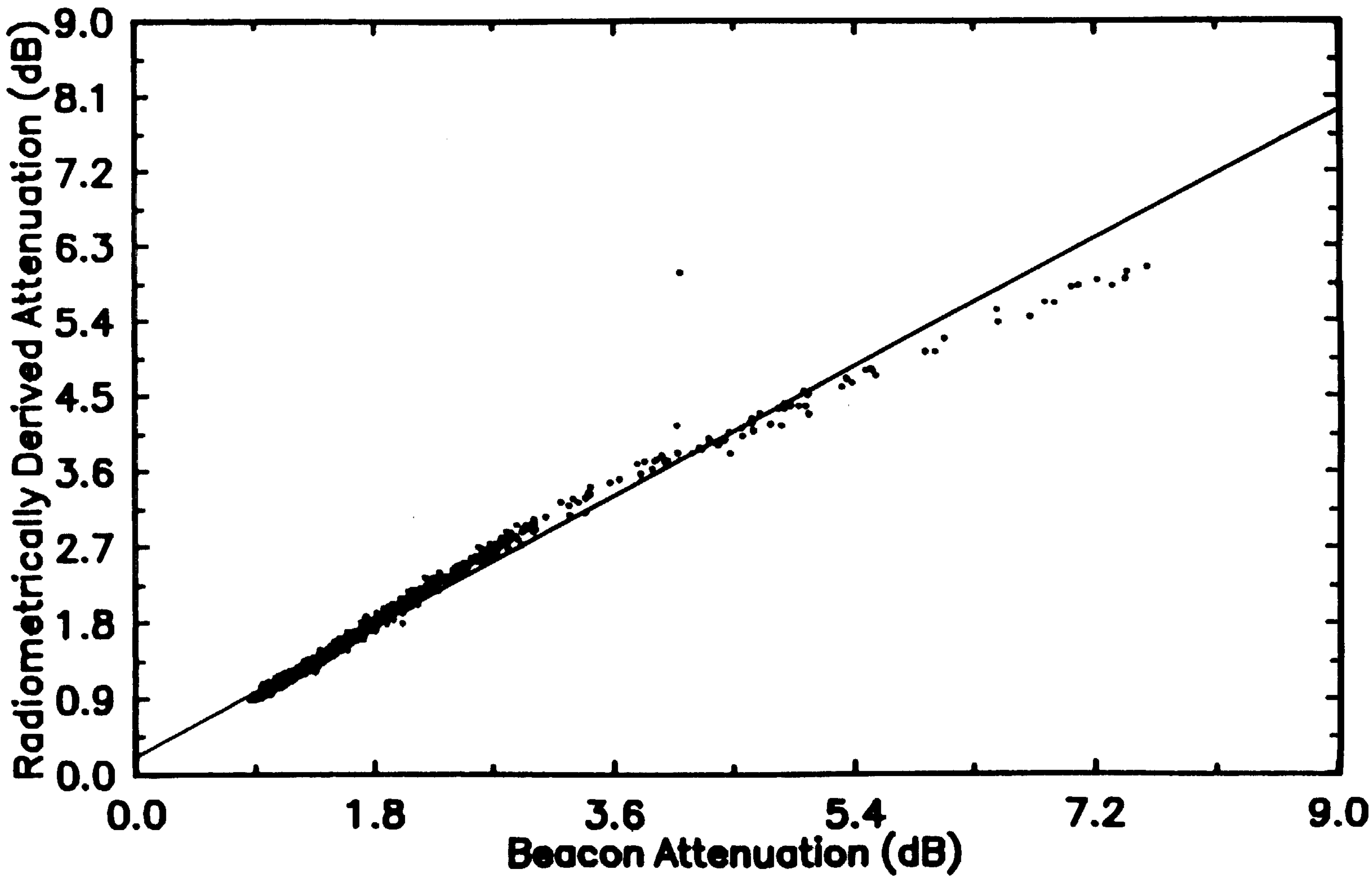

Figure 3. Scatter plot of attenuation predicted from radiometer measurements versus beacon measured attenuation referenced to free space for an event on January 20, 1991 lasting a few hours.

for attenuation in dB. In practice, A_{20} could be measured from a beacon or even a radiometer. Predictions can also be made from delayed 30 GHz attenuation as

$$A_{30}(t) = e + f\, A_{30}(t - t_o) \qquad (3)$$

Figure 4 shows the rms error for this last prediction method.

5. Conclusions

The experiment program at Virginia Tech has several unique opportunities. The collection of simultaneous data at three frequencies spanning the 12 to 30 GHz region is extremely useful in frequency scaling studies. This is possible because all links have the same path (14° elevation, 105° azimuth). The 14° elevation angle is relatively low and data in this region are also very useful because this is at the lower limit for CONUS coverage with domestic satellites. Our experiment records low-fade events accurately. This is valuable in amassing a database for low margin operational satellite links such as VSAT systems. Another feature of our OLYMPUS program is that it provides a test bed for ACTS due to the similarity of frequencies (ACTS beacons are at 20.2 and 27.5 GHz).

Initial results show that radiometer prediction attenuation agrees with beacon measured attenuation to the fractional dB level for fading up to 10 dB. Small baseline diversity, as expected, offers no improvement to rain fading, but does for scintillation events.

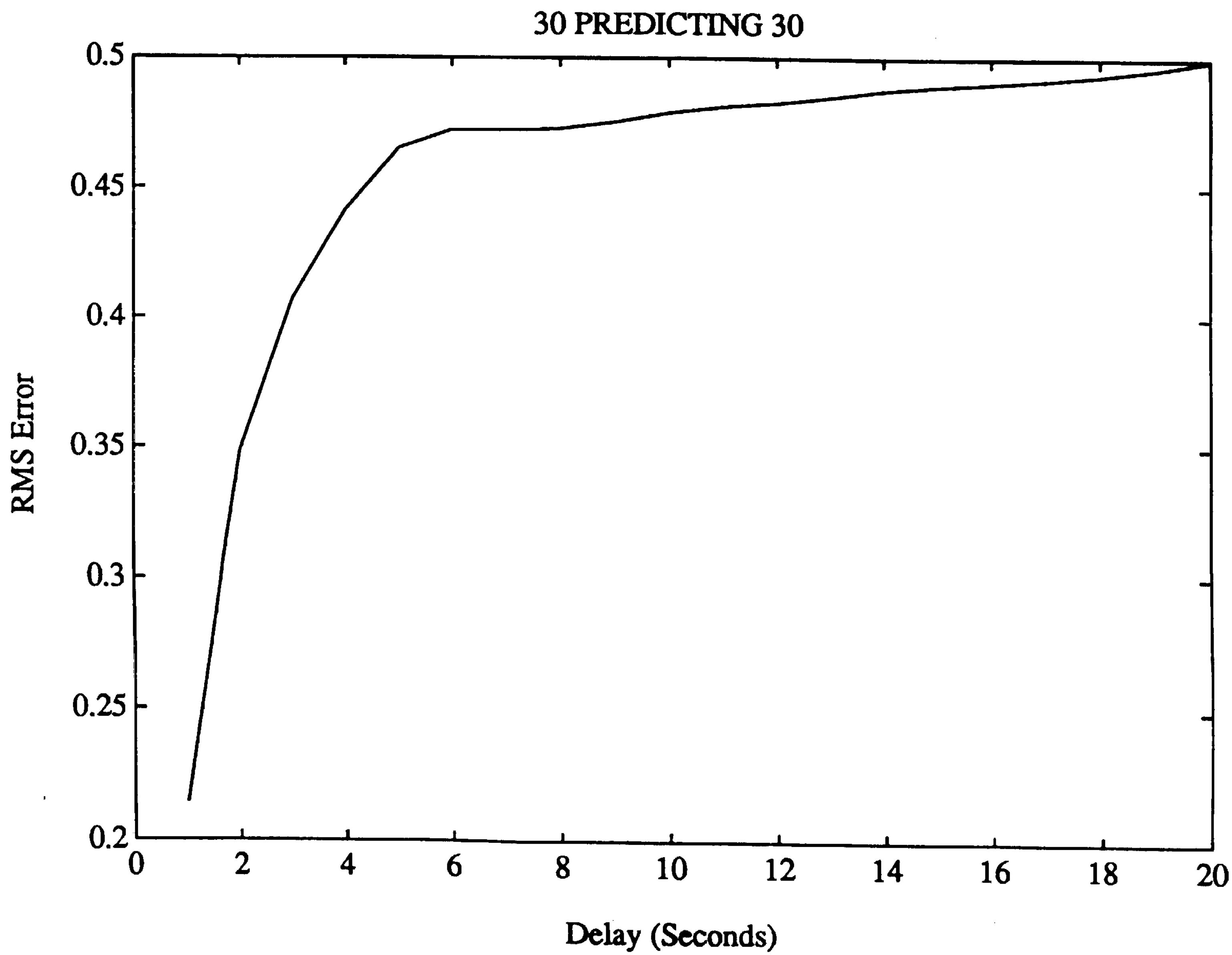

Figure 4. RMS error of predicting 30 GHz attenuation from an earlier 30 GHz attenuation level for an event of January 7, 1991.