

Study of HF Multipath and Doppler Measurements Using WWV/WWVH Scientific Modulation Signals

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Abstract

This paper summarizes a year-long data-collection and analysis effort using the HAMSCI Scientific Modulation signals transmitted by WWV and WWVH every hour. Multipath and Doppler fading profiles were calculated for two links: Massachusetts to Boulder, Colorado (WWV), and Hawaii (WWVH). Correlations between multipath, Doppler profiles, and Kp index were calculated. This paper also proposes a set of techniques for processing and using the WWV/H test signals.

Introduction

The goal of the measurement campaign described is to use the signal from the HAMSCI WWV/H Scientific Modulation Working Group to make high-resolution, long-term measurements of HF channel quality on a fixed set of paths and to develop processing routines to extract multipath and Doppler measurements from the broadcast signal.

The WWV/H Scientific modulation signal is broadcast by the NIST time standard radio stations WWV (Boulder, CO) and WWVH (Kauai, HI) in partnership with the HAMSCI WWV/H Modulation Working Group. The signal is transmitted on 2.5, 5, 10, 15, 20, and 25 MHz and was designed to aid researchers in studying ionospheric effects on radio propagation. WWV broadcasts the test signal at 8 minutes past the hour, and WWVH broadcasts it at 48 minutes past the hour, as part of each station's broadcast schedule. The signal lasts approximately 44 seconds of a 1-minute time block and consists of the following segments¹:

- 10-second voice announcement
- 2 seconds of Gaussian White Noise
- 1 second of blank time
- Phase Coherent 2, 3, 4, 5, kHz sine waves that drop down by 3 dB 9 times, with a duration of 10 seconds
- 1 second of blank time
- 8 seconds of linear up-chirps and down-chirps
- 2 seconds of blank time
- One-cycle of burst at 2.5 kHz frequency, repeated 5 times over the duration of a second
- 1 second blank time
- 2 seconds of Gaussian white noise
- 3 seconds of blank time

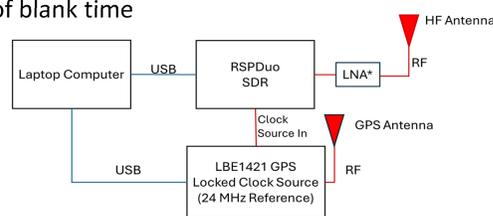


Figure 1: Block Diagram of measurement system

Method/Experiment

Data was collected using the equipment shown in Figure 1. Two stations were used in this study, each with a different HF-tuned antenna for collection. The primary location in Chelmsford, MA, used a "SuperAntenna", vertical monopole over ground, tuned to 10 and 15 MHz. The second location used a "MegaLoop ML 30+" Active Loop antenna with a frequency range of 0.5 to 30 MHz.

Data was processed using a MATLAB script processing chain shown in Figure 2.

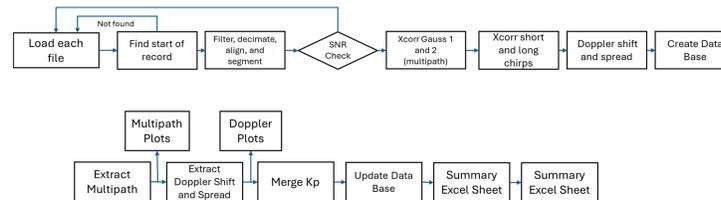


Figure 2: Signal processing chain code flow.

Data and Analysis

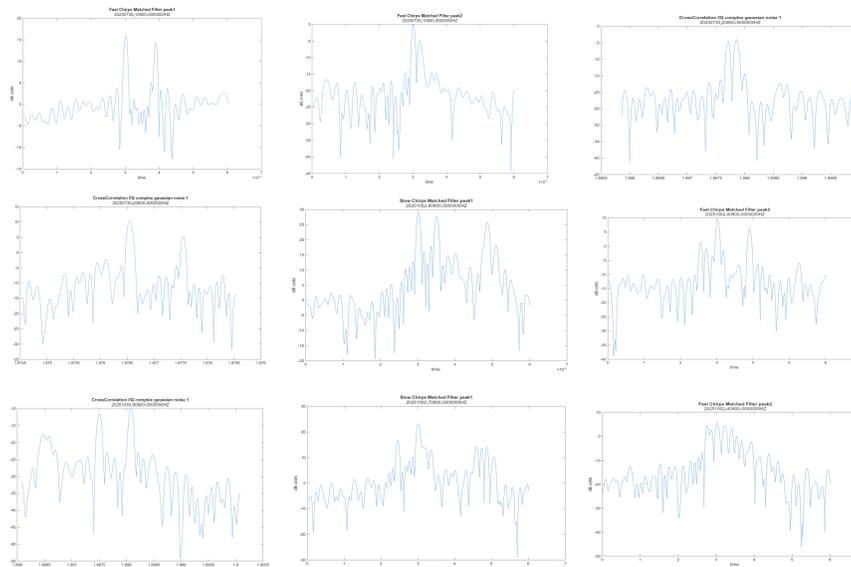
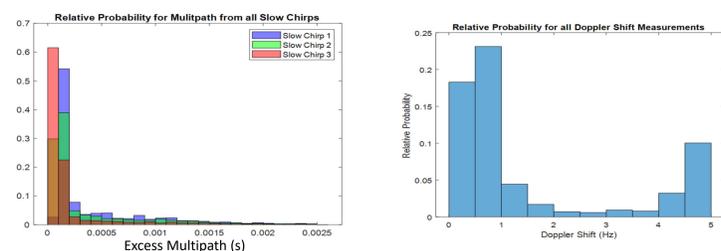
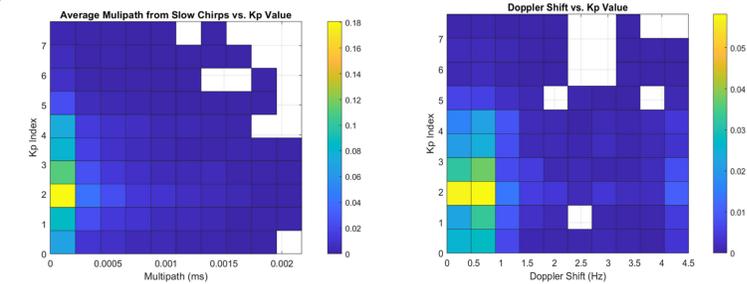


Figure 3: Multipath extracted from various parts of the signal showing distinct layers in the peaks



Figures 4-5: Multipath from Slow Chirps and Doppler Shift Probability Distributions



Figures 6-7: Relative Probability Distributions of Multipath and Doppler Shift as a function of Kp Value

Dates of Interest	
22-Aug-2025 19:08:00 UTC	Maximum Multipath Slow Chirp 1: 2.5 ms
03-Oct-2025 17:08:00 UTC	Maximum Multipath Slow Chirp 2: 2.5 ms
02-Oct-2025 02:08:00 UTC	Maximum Multipath Slow Chirp 3: 2.5 ms.
17-Mar-2025 20:08:00	Maximum Doppler Shift: 5 Hz
11-Nov-2025 18:08:00	Maximum Kp Value: 8.667

Table 1: Dates of interest throughout the collection period

Conclusions

- Multipath profiles can be extracted from the slow chirps, fast chirps, and Gaussian Noise. Gaussian noise would provide better results, but we need to increase the modulation index to improve SNR.
- Multipath exceeding 2 ms. was observed. Modes included multi-hop, multi-layer, and Auroral Scatter.
- Leverage data from the HAMSCI PSWS for continued study of HF channel conditions over a wider geographic area.

References

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 [2] Matzka, J., Stolle, C., Yamazaki, Y., Bronkalla, O. and Morschhauser, A., 2021. The geomagnetic Kp index and derived indices of geomagnetic activity. Space Weather, <https://doi.org/10.1029/2020SW002641>

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