UNCERTAINTIES IN PHASE AND FREQUENCY ESTIMATION WITH A MAGNETRON RADAR: IMPLICATION FOR CLEAR AIR AND PRECIPITATION MEASUREMENTS.

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1. INTRODUCTION

The Engineering Research Center for Collaborative Adaptive Sensing of the Atmosphere (CASA) is advancing the use of dense networks of low cost radars for atmospheric remote sensing applications. CASA's first technology demonstration test-bed (IP1) has been deployed in southwest Oklahoma for the past three years, and it consists of a network of four magnetron based, dual-polarization, Doppler radars. A number of the data products routinely obtained by the network rely on each radar's knowledge of their transmitted pulses phase and frequency, to compensate for the magnetron's frequency drift and random start-up phase values. Therefore, a set of tools is implemented at the radar node level to estimate the transmitted pulse's phase and frequency and use them where relevant. This paper will focus on the effects of the phase and frequency estimation uncertainty in clear air and precipitation measurements.

2. RECEIVED PHASE GENERAL EXPRESSION

For a typical magnetron radar with a drifting transmitted frequency and tracking local oscillator, a general expression for the coherent-on-receive, down-converted, received pulse phase can be written as

$$\Delta\theta_{T,R}[n,m] = Arg\left\{e^{j\left[2\pi(f_T[n]-f_{LO}[n])mT_s - 2\pi f_T[n]\tau + \phi_s(\tau)\right]}\right\} \tag{1}$$

where n is the pulse index, m is the range gate index, f_T is the transmitted frequency, f_{LO} is the down-conversion local oscillator frequency, T_s is the sampling period, τ is the pulse propagation time, and ϕ_s is the scattering phase.

Inspecting the previous expression it can be seen how in the case of estimating the absolute received phase (such as in obtaining a clear air refractivity measurement) the effects of changing transmitted and down-conversion frequencies should be compensated for in order to avoid biases in the final result. In addition, the phase of a target at a distance r from the radar is expressed in terms of range and the refractivity change along the path as

$$\Delta\theta_{T,R}(r) = \frac{-4\pi f_T}{c}\int^{r} n(\gamma)d\gamma \tag{2}$$

which is also dependent on the transmitted frequency.

Conversely, in all phase quantities that arise out of correlation estimates (such as Doppler velocity, Differential Phase) these effects are cancelled, as they remain constant during the measurement time interval. Another effect of a drifting transmitter frequency is a potential change in the receiver gain and differential gain values between polarizations, as the operating frequency point changes, if the operating frequency is not adequately tracked and accounted for.

In typical magnetron radars a hardware loop is used to track the transmitted frequency and adjust the local oscillator accordingly, making this operation transparent to the radar user and sometimes not allowing recording of the actual frequency values. The radar nodes in the CASA IP1 test-bed have a digital Automatic Frequency Control loop that estimates the transmitted frequency and adjusts a Numerically Controlled Oscillator, allowing to store both the estimated transmitted frequency and NCO frequency. These values can be employed to estimate the absolute received phase and to estimate refractivity, which will be affected by the error in the transmitted frequency estimation. Equally, the estimated transmitted frequency value can be used to track gain changes in the receiver that will affect reflectivity-based measurements.

This paper presents long term data on magnetron transmitter phase and frequency stability measurements from the CASA IP1 network, and the tools used to handle the frequency drift measurements for the corresponding application.