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C-band Meteorological Radar
Free-Sphere Calibration Procedure

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1.0 Introduction

Calibration of a ship-borne radar presents some unique challenges, not the least of which is the constant motion of the platform (the ship). Tethered sphere calibrations are difficult due to the fact that it is difficult to get the target far enough from the radar safely, plus the fact that the target is at the mercy of the winds vs. the tether, insofar as it's position is concerned. Know-source calibrations are almost impossible at sea as the source keeps disappearing behind waves. Solar calibrations are potentially viable provided the ship has quick access to the Internet in order to obtain solar flux measurements.

The sphere calibration provides a direct end-to-end calibration without undo assumptions, provided that the peak returns from the sphere can be measured, ensuring that the sphere is not between range gates, between beams, or otherwise in a position to reduce or compromise the returned signal. A free-floating sphere provides many opportunities (statistically) to see the peak returned signal. As the sphere recedes in range the peaks must follow a 1/range^4 curve which may be extrapolated back to the reference range (usually 1 km) to provide the desired calibration. A sphere has a very precisely known effective reflectivity given by:

Zsphere = (λ^4/π^5)*π*r^2

where:

Zsphere is the effective reflectivity of the sphere,
λ is the wavelength of the radar,
r is the radius of the sphere, and
^ is the exponentiation operator (e.g. 2^3 = 8).

2.0 Gathering Data

A 200 gram weather balloon with a light sonde attached will ascend at about 1000 ft/min, or about 5 m/s. If the wind relative to the ship is about 20 kts, or 10 m/s, then the balloon will run downwind of the ship at an elevation angle of about 23 degrees while increasing in altitude. The elevation angle will tend to decrease somewhat with height since wind tends to increase with height. Also, winds tend to veer counter-clockwise with height, so the track will tend to do the same thing.

To this date we use the following strategy:

1. Choose a time at which the ship is going to be on a constant heading at constant speed, and during which the wind relative to the ship is between 15-25 kts and less than about 30 degrees off the bow.
2. Set up a Sigmet scan centered downwind with an azimuth sector width of +/- 30 degrees from downwind and an elevation sector range of 10 to 30 degrees with a 0.5 degree increment. Sweep speed should be 12 degrees/second, speckle filter off, T should be 1st parameter recorded and V second. Clutter suppression should be off.
3. Set up Sigmet data acquisition to record Sigmet RAW-format files sweep-by-sweep.
4. Inflate the balloon and attach the sphere with about 2-3 meters of monofilament fishing line (monofilament line doesn't absorb water), and launch the balloon.
5. As soon as possible, start the Sigmet scan. Urgency is unnecessary since the sphere won't be seen for a few kilometers, at least 2 minutes, plus the targets closer than 8 km are frequently corrupted by multipath signals.
6. Watch the Sigmet Realtime Display for appearances of the sphere as a tiny dot in reflectivity (dBZ) moving out in range. Make a note of the azimuth and elevation.
7. As the sphere recedes, it is possible to restrict the sector angles and get more frequent returns from the sphere as follows:
   a) get into the 'Task Configuration' menu for the scan,
   b) edit the angle extents,
   c) stop the scan in the 'Task Scheduler' menu,
   d) save the task to disk in the 'Task Configuration' menu, then
   e) return to the 'Task Scheduler' and restart the scan.

The Sigmet system calculates reflectivities assuming a meteorological target, whose effective reflectivity decreases as 1/r^2. The return from the sphere is quite strong initially, but decreases with range as 1/r^4, rather than as 1/r^2. A 6 inch diameter sphere has an effective reflectivity of 27.15 dB at 1 km. At 40 km the effective reflectivity is 32 dB lower, or about –5 dBZ.

2.1 Setting up to reduce the calibration data

The software that exists to reduce balloon flight data is currently C-code which runs in an MSDOS window in DOS or Windows 3.1x/95/98/Me/2000/NT plus an m-code perusal routine for MatLab. The first step is to convert the Sigmet RAW data files to NCAR Field Tape Format files, a more user-friendly format. This is done as follows:

1) Open a special directory for the Sigmet *.RAW calibration files.
2) Download the Sigmet *.RAW???? data files from the radar host computer to the special directory.
3) Run the following script to convert the Sigmet RAW files into NCAR Field Tape files with a naming scheme indicating their time of creation and the elevation angle at which they were taken. NCAR Field Tape Format was chosen for compactness, efficiency, and ease of access using Matlab.

4) Run the following script, assuming one is in the target directory ~\target:

for %a in (<path>*.RAW) do <\pathname_to_sig2n.exe>\sig2n   %a <return>

This will convert all the RAW data files in ~\rawdata to NCAR Field Tape Format with a special naming convention. The filename is "RB" followed by HHMMSS.EEE, where:

HH is hours in the day,
MM is minutes past the hour,
SS is seconds past the minute, and
EEE is 10*elevation in degrees.

For example, file 'RB012234.235' was started at 1:22:34 Universal Time at an elevation angle of 23.5 degrees.

Following this conversion, there is a MatLab m-file which will allow searching through the files for sphere returns. This can be a time-consuming process, but one can conserve time by noting that only files within a narrow elevation/file extension need be examined.

To use the Matlab routine, start Matlab and:

1) set the Matlab variable "filename" to point to the file to be examined:
    filename = '\rbhdata\C010828.172\RAW\RB010422.285'
2) run radar0.m by typing:
    radar0
This will put up a reflectivity vs. time display as Figure 1 in Matlab. The sphere routine is usually obvious after a few kilometers and, when it appears, 'radar0' will print the range, az, el, and dBZ level in the Figure window. Repeated <return/enter> key hits will advance the display through the sweep. Slow down close to suspected sphere azimuth as you can't go back...you must start the file over. Note the peak reflectivity and range for that filename, then go on the the next file. 'filename' must be set to the target file in Matlab before starting 'radar0'. If the operator gets out of the file perusal before the end of the file, there is another m-file 'cl' which will close 'filename'. This prevents some odd problems with subsequent accesses to a file.
3) After all the obvious target returns are listed, correct them for range by adding 20*log10(R) to the return. This treats the sphere as a point target, which it is.
4) Linearize all the corrected returns by taking the inverse log of the corrected values: 10^(dBZcorrected/10).
5) Cull out outliers. This is a very subjective operation and subject to suspicion as well as abuse.
6) Average selected peak values.
7) Compute 10 times the log of the average to get the effective dBZ value of the sphere.   With the radar parameters set as they are, this should be about 35.2 dBZ.

NOTE: All of the above operations can be performed easily in a spreadsheet, such as Excel, Quattro Pro, etc.

The actual sphere reflectivity value at 1 km is pi*r^2I*l^4/pi^5, or radar cross-section (RCS) times lamda^4/pi^5. RCS for a sphere is just the cross-sectional area, or pi*r^2.