Bistatic Radar Operations Using DSS-13 and DSS-14
A Guide to Easy Observations

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Introduction

This note describes the normal operation of Bistatic Radar observations using DSS-13 and DSS-14. It also addresses a number of backup configurations that can be used to operate around some potential problems. I also provide a checklist of things that need to be tested prior to the experiment that should help assure success. Finally, there is a "commonly asked question" section that provides answers to many questions that have short answers. For questions that require longer answers, you may have to contact a member of the radar group by phone or e-mail.

The bistatic mode of operation is used in two different basic modes and several possible configurations. In modes, there are the usual CW and ranging differences, an there is bistatic meaning either one or two receiving stations are participating. When two stations are participating in receiving, the configuration is normally assumed to be as an interferometer, and normally this is a ranging experiment. It is also possible to use two channels per station, i.e., there can be two polarizations for one or both stations. In the case of near earth asteroids, there is normally only one receiving station, and DSS-14 assumes a mode of continuous transmission. This mode of operation greatly simplifies these experiments by alleviating the switching from transmit to receive modes at DSS-

14. We also use the DSS-13/14 combination for a number of joint experiments with the VLA. These experiments are always CW and without hopping the transmitter frequency.

I. General Considerations

Experiments using S-Band are relatively infrequent, so if S-Band is to be used, it is essential to get the entire system checked out a few weeks in advance of the experiment. This is especially true of the transmitter. The S-Band LNAs are transferred station equipment in the SPD cone and would normally be available. These LNAs normally have to be re-tuned to the radar frequency by the operations support staff. If DSS-14 is participating in receiving, X-Band operation normally uses the dual polarization radar LNAs, and a system temperature of roughly 14 deg K should be expected at zenith. If backup receivers are required, the station's X-Band masers can be used, however, the system temperature is much poorer, typically about 22 deg K. The reliability of the X-band transmitter has been improved significantly with the new, straight waveguide. Still, it is a good idea to schedule a transmitter test prior to any critical observation.

DSS-13 has the ability to receive two polarizations using the Ultra Low Noise Amplifier (ULNA) and one polarization the HEMT LNA at X-band. The outputs of these receivers are converted to 50 MHz for transmission to DSS-14 over fiber optics links. The system temperature of the ULNA is normally about 15 deg and the HEMT is closer to 35 deg K. In some cases, S-Band can be supported using the S/X feed which also employs a single channel HEMT. If the HEMT systems are to be used either for prime or backup purposes, the configurations and cabling need to be set up and tested in advance of the experiment. The ULNA always requires scheduling the delivery of liquid Helium to cool the system, and this needs to be done a week in advance of the experiment.

II. Continuous Wave Operation

a. Frequency Hopping and PLO Configuration

Generally CW experiments use frequency hopped transmission to help remove base line drifts and other spurious signals from the processed spectra. The hopping is currently carried out using the programmed local oscillators (PLOs), and a special "modulation" section of the command file must be set up to specify the number of hop states, the duration per hop state, the starting frequency, and the frequency step size. The transmission of hop encoded data is usually done with a fixed carrier frequency, i.e., not Doppler drifted in the up-link, but the current PLOs are capable of doing both. Normally, DSS-13 must be provided with a PLO configuration file to remove the Doppler shift during reception.

b. DSS-13 Bistatic Operation with the VLA

Bistatic observations using DSS-13 and the VLA require some special care in setting up the PLO at DSS-13. Transmission to the VLA uses up-link Doppler to cause the receive frequency at the VLA to be fixed. Obviously, the receive frequency at DSS-13 is not fixed, and a differential Doppler correction must be applied by the PLO. Simultaneously, it is possible to HOP the local oscillator frequency to simulate transmission of frequency hopping. This procedure is not quite as good as hopping the transmitter, but it is very effective in removing all spurious signals following the first mixer.

c. Data Acquisition Systems

Two data acquisition systems are currently in use. Goldstein's system is simple and very effective for most experiments. The new VME base based data acquisition system is still being tested, however, we expect this system to become the standard system in the near future. This system permits much larger FFT sizes, and greater selection of bandwidths and hopping parameters than the Goldstein system.

d. Kronheit Filters and Signal Levels

One of the most difficult activities in setting up the CW system is getting adequate signal level at the input to the samplers when the Kronheit filters are set to narrow bandwidths, i.e., less than 10kHz. It is essential to use the input and output 20 dB gain settings to bring the baseband level up so that there is at least 1 volt peak to peak at the sampler. The levels at the receiver output and the IF output should be checked for clipping, normally these have to be pushed to level where they just begin to clip.

III Ranging Experiments

a. Doppler Corrections of Frequency and Range Codes

Ranging experiments for bistatic operation are nearly always set up to operate with up-link Doppler correction so that the receiving station sees a fixed frequency. We have always transmitter up-link range code with differential range code correction on the down-links of all participating stations. When only one station is receiving, the polynomial for differential range will be all zeros, i.e., no correction is applied, and the range code comes in at a fixed baud rate.

b. Ephemeris Files and Associated Problems

The ranging program must read the ephemeris file to get the proper polynomials for drifting the frequency of the range code. This normally works without problems so long as the command file creates the proper file name for the ephemeris and the ephemeris has all the proper items in the order required by the coder configuration file. Things that go wrong are as follows:

1. The year number is wrong in the configuration file,
2. The wrong ephemeris products are indicated in the file,
3. The order indicated in the coder file does not agree with the order of the products in the ephemeris file,
4. The ephemeris file is in the wrong directory on the VAX,
5. There are multiple rise and sets in a given day, and the program is confused about which segment to use.
6. The program always searches for the previous day to see if the current time span is covered on that day, they may be no previous day present. Most of the above problems have rather obvious corrections. Items 5 and 6 are difficult enough to solve that it is a good idea to know about them in advance of the experiment. This may require hand editing a version of the ephemeris that has only the currently required items in the set. It is also a good idea to check that the proper solution has been found by putting the master radar clock on "simtime", then load and start the program to be sure it finds the ephemeris.

c. Link Delays

When bistatic ranging is used for ephemeris development, it is important to know the link delays as accurately as possible. This number can be entered in the range offset area of the coder configuration file so that it is taken care of properly. If this is not done, the location of the echo will depend upon the code period, and the echo could fall out of the sampled region. For planetary work where we are configured in the long code mode, the echo could be early and not visible. For asteroid work, we nearly always run in the short code mode and decode all possible range gates to that the echo will be visible somewhere in the display.

We have tried various ways to measure link delays in the past, but the quickest way is to set up the local loop-back configuration, and send the signal on one link to DSS-13, have them return it by coupling the cables together at the ULNA, and running the radar in the highest resolution mode (1/8 micro second currently).

d. Special Procedures for Interferometry

Radar interferometry is probably the most difficult experiment that we do in that it requires more things to be right than any other experiment.

Radar interferometry requires two or more receive sites simultaneously recording and processing data. For this to work, the signals from each station must be registered in both range and frequency, and any mis-registration will result in a reduced value for the cross power products between station pairs. Normally, the Doppler tracking ephemeris is sufficiently good that the relative ranges and Doppler frequencies between stations will not drift. Errors in the station coordinates may cause drifts in relative range and Doppler frequency, and in general the phase between stations is not stable for more that a few minutes at X-band due to antenna motions that are not modeled in the predicts and due to variations in the atmosphere and ionosphere. For that reason, integrations times should be kept under a few minutes. In cases where a Doppler correction is required, either voltages should be recorded, or the power average should be kept short. Range offsets can always be applied with type-ins while running the program. Aligning the range, requires zooming the display so that the details of the front of the echo can be seen clearly. Then estimate roughly how much to move the echo to get identical displays in all channels. Use the offset type-in to adjust each satellite station relative to one selected prime station (usually DSS-14). Then, check for for fringes using the cross-power display. The little vectors should show a systematic pattern and slowly rotate over a period of several minutes. If the vectors are random, it usually means that the range is mis-aligned, however, it is also possible that the frequency direction is reversed on one station or another. Beware of uncompensated high side LOs. DSS-13 has an uncompensated high side LO in the radar mode, and its signal is always spectrally reversed relative to DSS-14. This is usually corrected in the distributor configuration file by unloading I and Q correlators in reverse order.

d. Special Procedures for Stokes Parameters

Both DSS-13 and DSS-14 have dual polarization maser and receiver systems. It is possible to use the same signal processing "formation of cross power" to compute the Stokes parameters that give a full description of the state of polarization of the elements in the resolved radar target. Generally only circular polarizations are available, so we can easily form the circular polarization Stokes vector. As we have no way to accurately calibrate the phase difference between channels, it is not possible to interpret the angle associated with the cross powers, however, the magnitude does indicate extent of correlation between the two polarizations which is indicative of the relative proportion of a linear component of polarization.

As with interferometry, long averages of the cross power products tend toward zero due to slow drifts in phase caused by the ionosphere. One can think of this as the apparent orientation of the linear component changing direction due to Faraday rotation. Also, rotation of the target may change the viewing geometry such that the polarization properties change.

Most of what the precautions are the same measuring Stokes parameters as for interferometry, however, range and Doppler registration are not an issue unless multiple stations are being used. The range and Doppler for both polarizations associated with a single station are usually identical unless the receiver group delays are different for each channel. Still, it is a good idea to check the alignment and to be sure there is no inversion in the I-Q components of the signal that would reverse the spectrum of one polarization relative to the other. One can not say with any assurance that correlation should be seen in the cross power display.

IV. General Check List.

1. Check receiver temperatures at zenith. An be sure the dummy load isn't left on at DSS-13 when finished. It is usually a good idea to do a Y-factor measurement at DSS-13 and observe the same measurement at DSS-14. To do this, set the link level with the dummy load off, and drop the line level by 10 dB. Apply the dummy load, and the level should rise by about 13 dB at zenith. Both locations should observe roughly the same Y-factor value. Use this measurement to get the

system temperature by reading the dummy load temperature. DSS-14 should calibrate the NAR system if local reception is part of the experiment.

2. If the source is planetary, it is usually possible to see it radiometricly, do an on-off source temperature measurement and verify that it is near the planned value.

3. Do the transmitter pre-caliberation, and record the transmitter power. If this is to be modulated, apply the modulation to be sure nothing changes. If so, make a note of the power. For example, often the reflected power increases, and may trip off the transmitter if it exceeds the preset value. The transmitter occasionally may have to be operated at slightly reduced power to alleviate this problem.

4. Be sure all ephemeris products are ready, and the dates and times agree with those of the experiment plan.

V. CW Check List:

1. Turn off the range code,

2. Verify that the PLOs have been set up properly for loop back test, i.e., no Doppler polynomial,
    a. If normal mode, set up transmitter hopping.
    b. If VLA, be sure hopping on the transmitter is disabled, and set up hopper on DSS-13 PLO.

3. Run loop back test to be sure the hopper is operating properly and that the system is coherent.

4. Set up Doppler polynomials in the PLOs where required, and check to be sure the PLO frequency agrees with the DOPROG program.

5. Check all receiver levels for clipping and be sure the signal level is adequate. On Goldstein's system, the twool program to verify the levels and that the samplers are working properly.

6. Be sure the receiver protector attenuators are enabled.

7. Set up data acquisition program as directed.

8. Run trial cycle to be sure everything works.

9. Run cycles.

10. Be sure the antenna and sub-reflector are tracking properly. It is a good idea to verify that the antenna operator has set up the transmit and receive macros properly. These should contain the proper offsets for leading the transmit position.

VI. Ranging Check List:

1. Turn on the code, and start the data acquisition program in loop-back mode. The VAX data acquisition system must be running the proper configuration to set up the coders, otherwise, the binary phase code may not be running, or it may be running a code that was run for the previous experiment.

2. Set up the system to do a long loop-back up to the sub-reflector and back. This should be done even if DSS-14 is not participating in the receiving.

3. Set up the display system to use VersaTerm Pro. Check the display command file to be sure it is set up properly for loop backs. It should cover the early range gates, and the full frequency width. Be sure NODC is off.

4. Verify that the system is coherent by removing all PLO frequency offsets, then apply a positive transmit frequency offset that will move the echo about 8 frequency bins from dc. You may have to look at the configuration setup file to determine the proper value.

5. Note that the scope display must show modulation in both directions from center as the circle rotates. If this is not happening, there is something wrong with the signal driving the modulator.

6. Set up the PLOs with the proper Doppler polynomials, and remove any frequency offsets applied for loop-back testing.

7. Be sure not to turn off the code.

8. Load the data acquisition program and verify that the ephemeris products were found.

9. Set the receive levels. Then carefully calibrate the DC out of the samplers by adjusting the DC bias controls on the baseband mixer to bring the LEDs to maximum brightness. This is especially important for short codes that do not reject the dc as well as longer codes.

10. Enable receiver protection attenuators.

11. Verify that the system changes from transmit to receive operation properly.

12. Be sure the display is set up properly for cold-sky runs and normal reception.

VII. Some Commonly Asked Questions:

a. Questions with simple answers

1. Why don't I get an echo?
   a. This is the most frequently asked question, and the answer is that "if anything can go wrong, it will," so it is important to check everything.
   b. Check antenna pointing.
   c. Be sure the PLOs are running the proper Doppler polynomials, and that the you are not using an internal synthesizer on the HP-8662s
   d. Recheck the PLO frequencies against the DOPROG listing.
   e. If this is a ranging experiment, look through the above check list to see if anything has been missed.

2. Why isn't the oscilloscope display a circle?
   a. This normally indicates clipping or distortion in the receiver, IF amplifier, or in the baseband mixer or following filters (CW mode). Check for clipping at each location using the oscilloscope, and correct the problem by reducing the level.
   b. Occasionally, there is some problem with the modulator, or frequency synthesizer. Be sure the signal is a sine wave that is properly modulated.

3. Why is the signal level too low when looking at the Goldstein's twool program?
   a. This is usually a problem with the CW mode when the filter bandwidth is less than 10 KHz. This is difficult to correct, but can usually be corrected by observing the maximum level you can get without clipping from the receiver, the IF amplifier, and the baseband mixer.

4. Why does the transmitter power spectrum look weird?

a. In CW mode, the transmitter spectrum should be a single line that may hop in small frequency steps. If this is not the case, it usually means that some source of modulation is being applied. Check to be sure the coder switch in in CW mode.

b. In Ranging mode, the spectrum should appear to be roughly a (sin(s)/x)**2 function with a notch in the center. If this is not the case, the PN code may not be set up properly, the channel 4 coder is not working properly, there is a bad cable, or the level to the modulator is too low to switch the modulator.

5. Why is the echo chopped off at range gate 11?
   a. This is normally only a problem in long code mode. The first 10 gates in this mode are really the last of the correlators 256 gates. Move the echo back using a positive transmitter offset, or if receiving, use a negative receiver offset.

6. How come the display is screwed up?
   a. The display may have been left in a zoom mode, or the threshold may be set too high. It might be set in the wrong mode, i.e., it could be in a cross-power display or in a range profile mode. Check the display DSP configuration file< or call Denise for help.

7. The oscilloscope display rotates the wrong direction?
   a. The I and Q lines have been reversed. Note, because I and Q are labeled incorrectly, our display normally rotates clockwise for positive frequency offsets to the transmitter or loop-back synthesizer. The I and Q signals are reversed at the oscilloscope. I normally goes to the X axis, and Q goes to the Y axis.

8. Why is the loop-back echo negative in frequency?
   a. This could be the same problem as #7, but it could also be due to the order of unloading the correlators in the configuration file. In some cases, this is the correct way of operation to force DSS-14 to agree with DSS-13 which has an uncompensated high side LO. Normally, DSS-13 has to have the I and Q signals reversed to agree with DSS-14.

9. Why are there two loop-back echoes either side of DC?
   a. This normally indicates that the I or Q channel signals are missing. In this case, positive and negative frequency can not be distinguished.
   b. The dc calibration of the A/D converters is wrong, and one of the LEDs may not be indicating maximum brightness.
   c. The A/D converter is bad or the baud integrator is bad, and you should configure for a different channel.

10. Why do the sampler LEDs dim or go out as the input level is increased?
   a. This usually indicates that there is distortion in the signal or non-linearity in the sampler or baud integrator. Normally, the samplers can be over driven significantly without drifting to one side or another. However, defects in the samplers or errors in the digital baud integrators can cause drift problems. Check another channel to see if it behaves better, if so reconfigure the receive channel by modifying the command files.

b. Questions Unanswered

1. Why don't I get an echo?
   a. Occasionally we can not answer this question. It seems that sometimes the gods of radar conspire against us sending us a small target, or cloudy nights for visible astronomy so the ephemeris is not good, or power failures that wipe out the transmitter and computers. Have faith that there will always be new targets, but if we miss too many there may not always be funding. There will always be more targets than funding to bounce radar off them, and the gods of radar seem to have established the $ too.