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APPLICATION NOTE
FSA-003 - BROADBAND ADCP WATER-PROFILING MODES
DATE/REV: 04DEC98 / 2
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NOTE: Sentences that were changed by Revision 1 begin with [R1].

ABSTRACT: Explains the water-profiling modes available in BBADCP systems as of 01JAN97.

INSTRUMENT/PROGRAM APPLICABILITY: All Broadband ADCPs (BBADCP)

0 - INTRODUCTION

This application note explains the water-profiling modes available in BBADCPs as of 01JAN97. We will explain the pros and cons of each mode. This information should help you select the best mode for your particular data collection site. Some details are contained here but not all. As RDI learns more from your experiences, we will be able to add information to help you better collect data.

For each mode, we provide a general description, an explanation of the best place to use this mode, specifics about the mode, and any setup considerations.

We do not discuss bottom-track modes, only water-profiling Modes 1, 4, 5, 7, and 8. Modes 2 and 3 have been discontinued, and Mode 6 is not known well enough to discuss here.

1 - WATER-PROFILING MODE 1 (WM1)

General Description - This is our most robust mode of operation. It allows for good data collection in all environments. It allows depth cell (bin) sizes from 0.10 m (for 600 and 1200-kHz ADCPs only) to 32 m (75-kHz).

Best Use Areas - Mode 1 is good for all areas. It works well in areas of slow currents, turbulent currents, strong shears, low backscatter concentrations (or where signal returns are apt to be weak such as in depths greater than 1000 meters), high background noise (such as being used from a ship), and in areas where the water changes from shallow (1 m) to deep(>6 m).

Specifics - The standard deviation is set after you have selected the bin size (WS command) and the ambiguity velocity (WV). The ambiguity velocity tells the ADCP what maximum velocity it will see. If you are operating the ADCP from a moving platform, the maximum velocity would be the ADCP's maximum speed (motion through the water) plus the maximum water speed. We call this the maximum "apparent velocity" the ADCP will see.

Setup Considerations - To set up Mode 1 correctly, you must have an idea of the maximum apparent velocity to set the WV command. The minimum suggested setting for WV is 100 cm/s. WV is set by using the following formula:

WV = (max. apparent velocity in cm/s) * (sin B) * (1.5)

Where:
B = Beam angle
(1.5) = The highest safety margin. You can reduce this safety margin if you are sure you will not exceed the maximum apparent velocity. We recommend a minimum safety margin of 1.1.

The maximum setting for WV is 700 cm/s (WV700). Higher settings will produce bad velocity data.

The Mode 1 profiling range can be increased through the use of the WB command. WB selects the operational bandwidth of the system. The wider the bandwidth, the shorter the range. This is because the signal-to-noise ratio is decreased when you use a wider bandwidth. The down side to using a narrower bandwidth is an increase in the standard deviation and a reduction in the maximum ambiguity velocity.

The default bandwidth setting is WB0, which is the widest bandwidth possible. The next setting (WB1) increases the standard deviation by a factor of 2 to 3 times over the WB0 setting. This setting is available in all BBADCPs. The maximum ambiguity velocity setting associated with WB1 is WV425 (425 cm/s). Settings beyond this will produce bad velocity data.

The Phase 3 BBADCP (CPU firmware versions 5.xx) allow for an even narrower bandwidth setting. In this case, WB2 can be used. The standard deviation is increased by 5 to 6 times over the WB0 setting. The maximum ambiguity velocity setting associated with WB2 is WV200 (200 cm/s). Settings beyond this will produce bad velocity data.

2 - WATER-PROFILING MODE 4 (WM4)

General Description - Mode 4 is our "all purpose" mode. It works in most environments and typically gives the lowest velocity standard deviation for a given setup. It allows bin sizes from 0.25 m (for 600 and 1200-kHz ADCPs only) to 32 m (75-kHz).

Best Use Areas - Mode 4 is ideal for areas where the water has the same general flow from surface to bottom, but may change from a slow-moving speed to higher speed such as in tidal flow measurements or for river current measurements. This mode is also good in fixed moorings and on slow-moving (less than 5 knots) platforms.

Mode 4 is not good to use if the water is turbulent or has high shears, low backscatter, depths greater than 1000 meters (because of low backscatter), or high noise floors in the first 6 m (for 1200-kHz ADCPs), 12 m (600-kHz), 23 m (300-kHz), 46 m (150-kHz), and 92 m (75-kHz). Additionally, if the water is shallower than the aforementioned depths, Mode 4 will not work if we assume the following bin sizes: 1 m (1200-kHz ADCPs), 2 m (600-kHz), 4 m (300-kHz), 8 m (150-kHz), and 16 m (75-kHz).

Specifics - Ambiguity velocity does not affect Mode 4 because it uses the upper portion of the profile to resolve the ambiguity velocity. This is done through a special processing technique.

Note that the only way the ADCP can determine if the Mode 4 ping will be successful is based on the correlation values in the first part of the profile. If the correlation is not high enough (approximately 127 counts), or if there is not enough water data to use (e.g.; shallow water), it will reject the Mode 4 ping.

Unfortunately, there are times when the ADCP thinks the data is valid, but due to the high shear, turbulent water, ringing, or second bounce data (where the signal bounces off the bottom/ surface and still appears as the next bin of data), the Mode 4 ping thinks it has made an accurate ambiguity velocity measurement. This ambiguity velocity estimate is wrong and will bias the entire profile. Therefore, you must know the above limitations, and must not use Mode 4 when any of the listed conditions can or may happen.

Setup Considerations - Although Mode 4 needs no other setups to operate, the ADCP can automatically switch from Mode 4 to Mode 1. If the ADCP determines that a Mode 4 ping cannot be processed, it checks a user-set switch to see if it should switch to Mode 1. This switch is controlled by the WW command, which has a default of WW004. This means if the ADCP fails to perform a Mode 4

operation during two consecutive pings, it will switch to Mode 1. It will then stay in Mode 1 for the next four pings (WW004). On the fifth ping, it will again try a Mode 4 ping. If the Mode 4 ping fails, the ADCP will stay in Mode 1 for four more pings. If the Mode 4 ping is ever successful, the ADCP will stay in Mode 4 operation until two consecutive pings fail again. NOTE: Since the ADCP will switch to Mode 1 when necessary, you must also set up the ambiguity velocity (WV) as described in Section 1.

Note that during this process, the ADCP always records the mode you initially selected when setting up the ADCP. That is, the Leader data always records Mode 4. There is no indication that the ADCP ever switched to Mode 1. If you wish to have only Mode 4 pings used during ADCP operation, you must set WW to WW000.

3 - WATER-PROFILING MODE 5 (WM5)

General Description - Mode 5 is our high-accuracy, shallow-water mode. Mode 5 lets you use bin sizes from 5 cm (1200-kHz ADCPs) to 50 cm (300-kHz). Mode 5 allows for very low standard deviation (less than 3 cm/s) in shallow water. [R1]Mode 5 is intended to be used with bottom tracking enabled.

Best Use Areas - Mode 5 is ideal for shallow water, fixed measurements (8 m and less; range depends on frequency: 4 m (1200-kHz), 6 m (600-kHz), 10 m (300-kHz)), or for slow-moving platform measurements where water velocity flows are very low (less than 100 cm/s).

Mode 5 is not good for areas where there is shear, turbulence, background noise, or fast ADCP motion (above 2-3 m/s). If high shears, turbulence, background noise, or fast ADCP motion occurs, the ADCP will not collect data.

Specifics - Mode 5 is ideal for shallow water environments (8 m and less; range depends on frequency). As such we do not mention the performance of the 150 and 75-kHz ADCPs with Mode 5. The lower-frequency ADCPs require minimum blanking distances that make them impractical for shallow-water applications.

[R1]Mode 5 uses pulse-to-pulse correlation. Mode 5 transmits a very short encoded pulse, receives information from that transmission, and when the signal has traveled twice the distance to the bottom, the ADCP transmits another pulse. The ADCP knows the distance to the bottom based on the Bottom-Track depth, so it is important to collect bottom-track data when using Mode 5. [R1]The two transmitted pulses are processed (or correlated; pulse-to-pulse correlation) to create the velocity estimate. The standard deviation is very low with Mode 5 because there is a relatively long lag between the two pulses. However, due to the long lag, the maximum velocity that can be measured is limited.

The range of Mode 5 is limited by two factors: (1) the very short encoded pulses used, and (2) the maximum velocity that is needed to be measured. These pulses do not put much energy in the water, so the signal return is weak. The deeper the profile, the slower the water must move or an ambiguity error will occur. There are cases when the water is very uniform (i.e.; no shear or turbulence) and is very slow (i.e.; less than 15 cm/s) such that the range can be as much as double what is specified above.

Setup Considerations - Mode 5 must use WZ05 (lag setting) for most deployments, which limits the profiling range. The higher WZ is set, the lower the profiling range. WZ05 provides for the deepest possible range. The ADCP automatically adjusts this setting higher based on the depth of the water. Therefore, for most applications, bottom-track should also be turned on.

Bottom-track is also important because Mode 5 places two pulses in the water column at once. We must keep both pulses from returning signals from different parts of the water column at the

same time. The bottom-track depth lets us time the transmission of the second pulse to occur at the same time the first pulse is bouncing off the transducer face.

There are some applications where you may wish to obtain only valid data near the instrument when the bottom is out of range of the ADCP. In these cases, the setting of WZ05 will still work. It allows the ADCP to collect data as deep as it can even though the bottom-track processing will not tell the ADCP to send the second pulse.

4 - WATER-PROFILING MODE 7 (WM7)

General Description - Mode 7 is our extended range mode. Mode 7 lets you extend the range of the ADCP about 15-20% farther than a standard Mode 1 setup (i.e.; you are not using the WB command) or in a Mode 4 setup. It will provide a standard deviation that is about three times that of the equivalent Mode 4 setup.

Best Use Areas - Mode 7 is ideal for fixed deployments (bottom or in-line moorings), stable platforms (surface buoy), and slow moving platforms (less than 3 knots) in calm to moderate sea conditions, where the bottom/surface is out of range of the Mode 7 profiling range.

Mode 7 does not work well on faster moving platforms or when the sea conditions are rough. The rough seas cause many drop outs in the data and some ambiguity resolving problems.

Specifics - Mode 7 uses a very short "pre-ping" that is sent out to resolve the ambiguity velocity just before the profiling ping is sent out. The pre-ping does not have much energy and can resolve a very high ambiguity velocity. However, this pre-ping will cause a bump in the echo intensity data and bias the velocity component in 1 to 3 bins of data whenever the bottom/surface is in range of the profiling ping.

Mode 7 has particular problems with highly dynamic seas or when the platform the ADCP is mounted on moves quickly or wildly. This is because the short pre-ping is lost in the noise generated by the seas or the moving platform. Additionally, if the ADCP is in high motion, it will resolve the ambiguity velocity with the pre-ping, but this pre-ping may not be measuring the same water that the profiling ping is measuring. This type of environment is often seen on ships in rough seas and open ocean work.

Setup Considerations - Mode 7 does not require any other setup. However, remember that whenever the bottom/surface is in range, there will be at least one bin that will be contaminated by the pre-ping bouncing off the bottom/surface. If this is a concern, we recommend using Mode 1 and the WB1 command.

5 - WATER-PROFILING MODE 8 (WM8)

General Description - Mode 8 is our robust shallow-water mode. Mode 8 lets you use bin sizes from 5 cm (1200-kHz ADCPs) to 50 cm (300-kHz ADCPs). The standard deviation of Mode 8 is about 3-5 times greater than Mode 5 (or 10 cm/s) in shallow water.

Best Use Areas - Mode 8 is ideal for shallow water (8 m and less; range depends on frequency: 4 m (1200-kHz), 6 m (600-kHz), 10 m (300-kHz)), where there is any shear, turbulence, background noise, or fast ADCP motion (maximum 4 m/s). Mode 8 can be used in fixed measurements or slow-moving platform measurements where the water velocity flows are very low. However, Mode 5 is better suited for those areas.

Note that if the shears, turbulence, background noise, or ADCP motion are too great, the ADCP will not collect data.

Specifics - Mode 8 is ideal for shallow water environments (8 m

and less; range depends on frequency), and therefore we do not mention the performance of the 150 and 75-kHz ADCPs with Mode 8. The lower frequency ADCPs require minimum blanking distances that make them impractical for shallow-water applications.

[R1]Mode 8 uses pulse-to-pulse correlation. Mode 8 transmits a very short encoded pulse, receives information from that transmission, and when the return signal hits the transducer face, the ADCP transmits another pulse. These two pulses are processed to create the velocity estimate. The standard deviation is very low with Mode 8 because there is a relatively long lag between the two pulses. [R1]Mode 8 estimates velocity based on the position of the correlation peak, therefore it has no ambiguity problem. This is why it can operate in areas that Mode 5 cannot. [R1]However, this method of estimating velocity has a higher standard deviation as compared to Mode 5 operation.

The range of Mode 8 is limited by two factors: (a) The very short encoded pulses used, and (b) The maximum velocity that is needed to be measured. These pulses do not put much energy in the water so the signal return is weak. The deeper the profile, the slower the water must move or an ambiguity error will occur. There are cases when the water is very uniform (i.e.; no turbulence or shear) and is very slow (less than 15 cm/s) such that the range can be double what is specified above.

Setup Considerations - Mode 8 must use WZ05 (lag setting) for most deployments, which limits the profiling range. The higher WZ is set, the lower the profiling range. WZ05 provides for the deepest possible range. The ADCP automatically adjusts this setting higher based on the depth of the water. Therefore, for most applications, bottom-track should also be turned on.

Bottom-track is also important because Mode 8 places two pulses in the water column at once. We must keep both pulses from returning signals from different parts of the water column at the same time. The bottom-track depth lets us time the transmission of the second pulse to occur at the same time the first pulse is bouncing off the transducer face.

There are some applications where you may wish to obtain only valid data near the ADCP when the bottom is out of range of the system. In these cases, the setting of WZ05 will still work. It allows the system to collect data as deep as it can.