Authenticatable Tracking for Secure Nuclear Containers Using Broadband Delay Between Multiple Points

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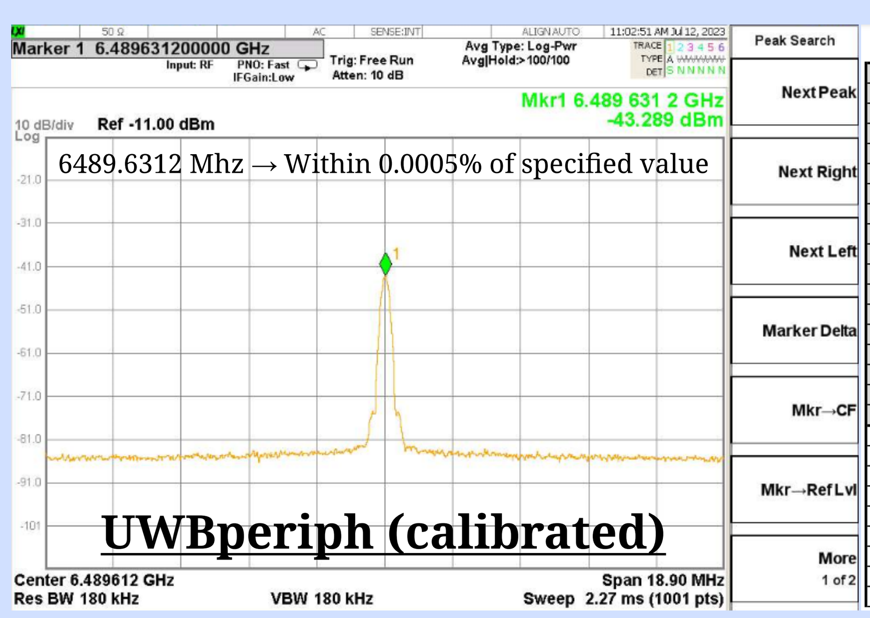
Introduction

The Authenticatable Container Tracking System (ACTS) project aims to provide a system that allows verifiable tracking of nuclear containers using communication between custom tags attached to assets and anchor stations placed around a target tracking area. This tracking would be accomplished by utilizing the delay in ultra-wideband ping signals between devices to calculate a one-dimensional distance. Distances between different anchor devices would then be combined to calculate a final position. Because we are using broadband, there are numerous regulations limiting allowable transmit power levels, so as not to interfere with other devices. To calibrate the transmission power, we must characterize and match a demo board, the EVB1000, which produces signals that have been verified to be below the legal limit.

Characterizing the EVB1000 Signal

EVB1000 ID	Power Peak Average (dBm)	Center Frequency (kHz)	From Target Power	From Target Frequency
EVB106090	-41.3	6502065	0	12465
EVB106092	-41.4	6493986	0.1	4386
EVB105873	-41.2	6487903	0.1	1697
EVB106137	-41.4	6507081	0.1	17481
EVB106009	-41.3	6493117	0	3517
EVB106587	-42	6491406	0.2	1806
EVB106107	-42.1	6495113	0.8	5513
Average	-41.45714286	6495810.143		
Max	-41.2	6507081		
Min	-42.1	6487903		
Range	0.9	19178		
Target	-41.3	6489600		
Average from Target	0.185714286	6695		
Max Above Target	0.1	17481		
Max Below Target	0.8	1697		
Absolute Max from Target	0.8	17481		
Standard Deviation	0.299205297	6571.927227		

In addition to transmit power, we also characterized the center frequencies for each demo board. This gives us a baseline of what is an acceptable level of frequency error.



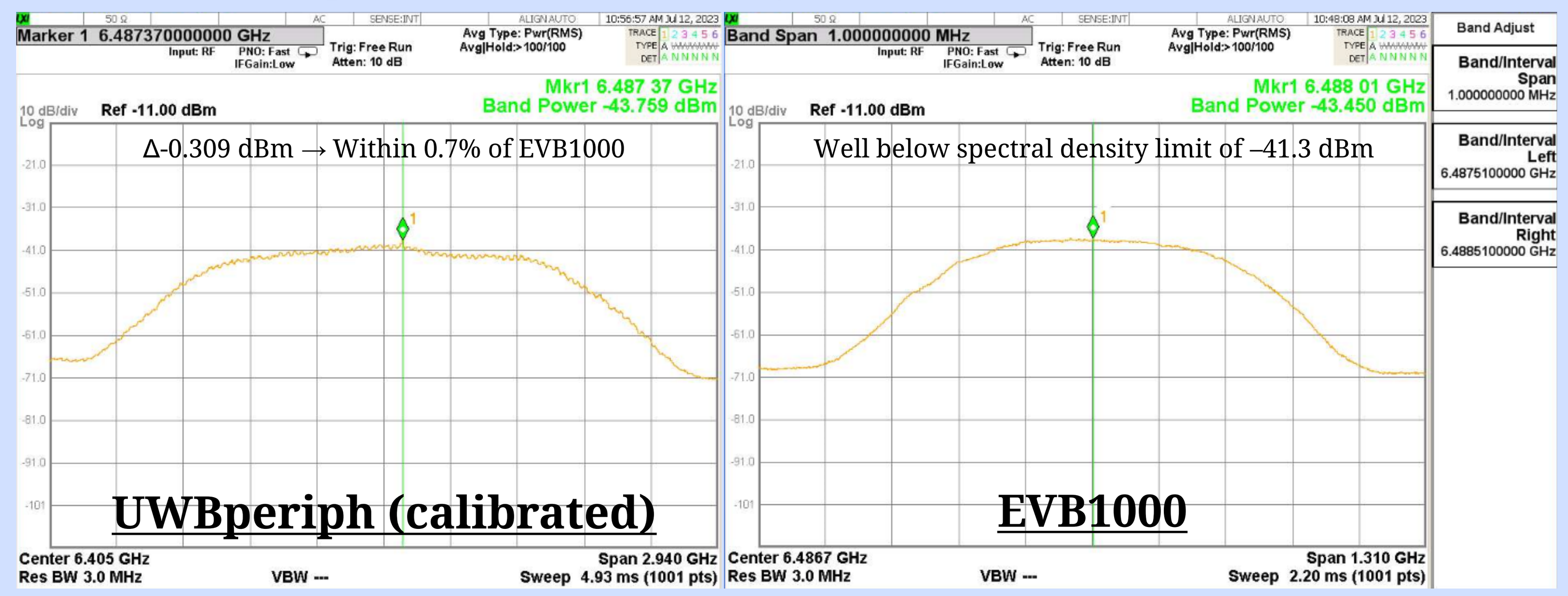
MSP ID	Center Frequency (kHz) "0"	"1"	"2"	"3"	From Target "0"	"1"	"2"	"3"
8254-31945994-0034-0045	6489598	6489581	6489564	6489547	2	19	36	53
8254-31945994-003A-0033	6489626	6489608	6489591	6489575	26	8	9	25
8254-31945994-0038-0028	6489648	6489630	6489613	6489597	48	30	13	3
8254-31945994-003A-0035	6489611	6489594	6489577	6489562	11	6	23	38
8254-31945994-003A-003B	6489585	6489568	6489552	6489536	15	32	48	64
8254-31945994-0039-001D	6489619	6489602	6489586	6489570	19	2	14	30
8254-31945994-0036-0039	6489621	6489603	6489586	6489569	21	3	14	31
8254-31945994-002B-0046	6489600	6489583	6489566	6489549	0	17	34	51
8254-31945994-0039-0047	6489639	6489622	6489606	6489589	39	22	6	11
8254-31945994-0037-005D	6489584	6489567	6489551	6489535	16	33	49	65
8254-31945994-0035-0032	6489599	6489582	6489566	6489550	1	18	34	50
8254-31945994-0037-0052	6489649	6489631	6489614	6489597	49	31	14	3
8254-31945994-0038-002F	6489612	6489595	6489578	6489562	12	5	22	38
8254-31945994-0036-0005	6489626	6489608	6489591	6489574	26	8	9	26
8254-31945994-0037-0029	6489626	6489609	6489592	6489576	26	9	8	24
8254-31945994-0039-004B	6489616	6489597	6489578	6489562	16	3	22	38
8254-31945994-003A-003D	6489610	6489593	6489576	6489559	10	7	24	41
8254-31945994-0038-002E	6489623	6489604	6489586	6489568	23	4	14	32
Average	6489616.222	6489598.722	6489581.833	6489565.389				
Max	6489649	6489631	6489614	6489597				
Min	6489584	6489567	6489551	6489535				
Range	65	64	63	62				
Target (EVK1000)	6489600	6489600	6489600	6489600				
Average from Target	20	14.27777778	21.83333333	34.61111111				
Max Above Target	49	31	14	0				
Max Below Target	16	33	49	65				
Absolute Max from Target	49	33	49	65				

Note: 0-4 refers to specific trim calibration register values in the DW1000.

Center Frequency of Peak Trace Average for UWBperiph in Continuous Wave Mode (very precise frequency span); target frequency for Channel 5 = 6,489.6 MHz.

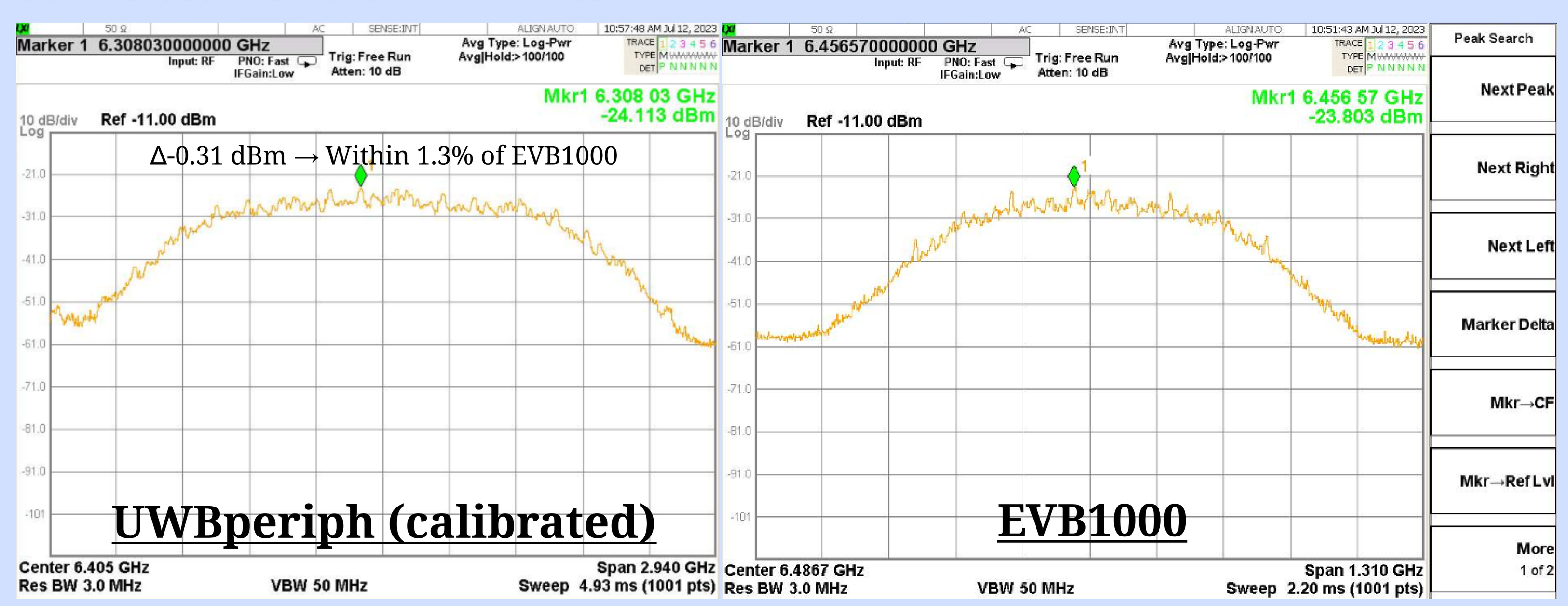
Calibrating Transmission Power

Now that our center frequency is calibrated, we will use a different transmission mode: continuously transmitting across a wide band, to better calibrate our transmission power. The specific legal requirement pertains to power over a 1MHz Band. We will first measure the waveform of the EVB1000 and then attempt to match its amplitude. (Note: the differences in span are due to test configuration, not calibration.)



Peak Band Power of Trace Average Over 1MHz for Both EVB1000 and UWBperiph; must be less than –41.3 dBm as per spectral density regulations.

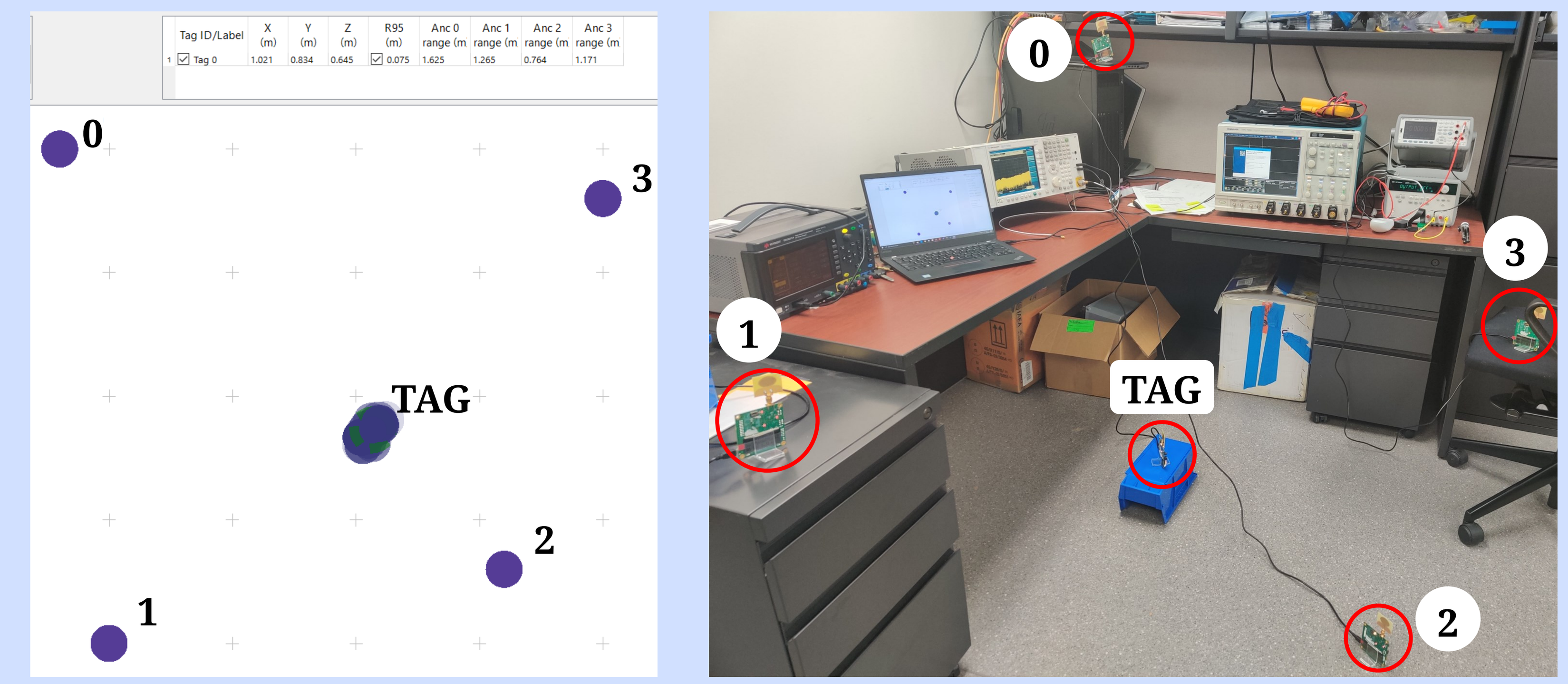
Because we are only examining the trace average of the wave, there's no real guarantee that it is properly configured. It could be possible that we have a lower transmission rate and a higher overall transmit power, resulting in an evened out curve that looks the same as the EVB1000s, yet does not properly match the signal. To ensure this is not the case, and to prevent transmitting over the legal power limit even when enabling Smart TX Power Control, we should also ensure that the maximum transmit power is the same between the two devices.



Peak power Max Hold over 30 seconds for both the EVB1000 and UWBperiph; shows that the transmission power is actually calibrated, rather than just set to a value that matches the band power at a different misconfigured pulse rate.

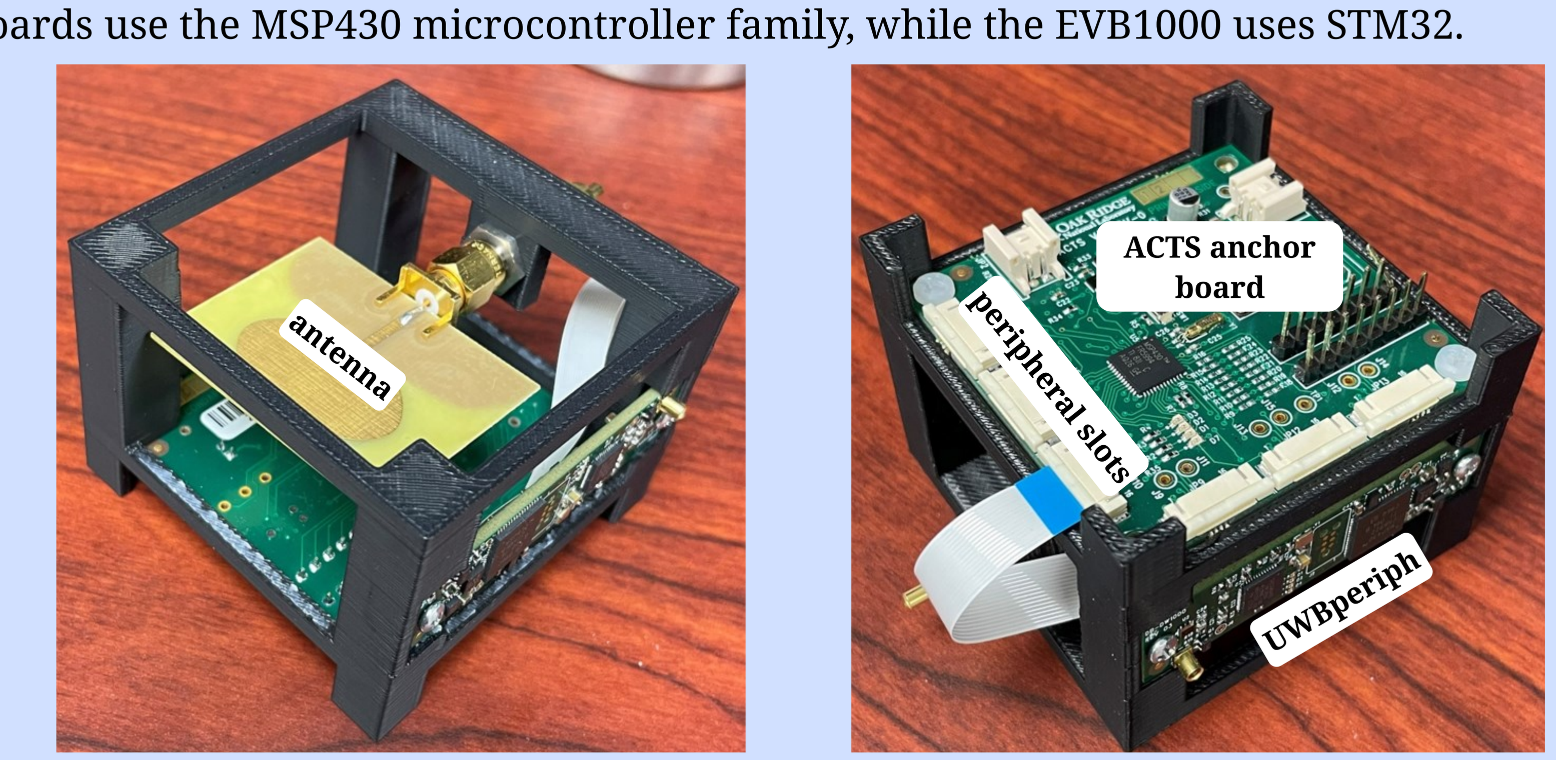
Ranging Between Devices

With our transmissions working and calibrated, we can now move on to implementing ranging between tags and anchors using trilateration, which can determine the estimated position of a target (any desired tag) given four straight-line distances from known points (our anchors) to the target. Because we will likely have a multitude of anchors scattered across the target area, we will use a technique called multilateration, which enhances the accuracy of the location determination by using multiple anchors to cross-verify the position of the tag. This method helps to reduce any potential errors and provides a more precise and reliable positioning system.



Demonstration of Trilateration Ranging Between 4 Anchor EVB1000s and 1 Tag EVB1000

Currently, we have trilateration ranging working on the EVB1000s, and are working on porting the code to our anchor and tag boards, which is fairly involved because our boards use the MSP430 microcontroller family, while the EVB1000 uses STM32.



Prototype Anchor Assembly in Custom Enclosure: ACTS anchor board attached to a UWBperiph via a SPI peripheral slot. A tag device would consist of only a UWBperiph.

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