Copy No.________

Defence Research and Development Canada
Recherche et développement pour la défense Canada

DEFENCE DÉFENSE

Some matched filtering experiments in Bedford Basin with the MMPP transducers

J. Fawcett
J. Sildam
V. Crowe
T. Miller
M. O'Connor
M. Rowsome

Defence R&D Canada – Atlantic

Technical Memorandum
DRDC Atlantic TM 2005-133
July 2005

Canada

Some matched filtering experiments in Bedford Basin with the MMPP transducers

J. Fawcett

J. Sildam

V. Crowe

T. Miller

M O'Connor

M. Rowsome

Defence Research & Development Canada Atlantic

Technical Memorandum

DRDC Atlantic TM 2005–133

July 2005

Author

John Fawcett

John Fawcett

Approved by

Ron Kuwah

Ron Kuwahara
Head/Signatures

Approved for release by

Kirk Foster
Chair/Document Review Panel

Abstract

In this report we describe experiments carried out in Bedford Basin, Halifax near the DRDC Atlantic barge. The high and medium frequency Multi-Mode Pipe Projector transducers were deployed from a Canadian Navy Fleet Diving Unit jetboat and the transmitted pulses recorded by a hydrophone deployed within the DRDC Atlantic barge. A variety of different pulses types were used from various ranges. Some of the recorded time series are presented in this report as well as the results of match filtering these time series with the input (before spectral compensation) pulses

Résumé

Le présent rapport décrit les expériences effectuées dans le bassin de Bedford, Halifax, près de la barge de RDDC Atlantique. Des transducteurs munis d'un projecteur à tuyau multimode à fréquences hautes et moyennes ont été déployés à partir d'une embarcation propulsée par hydrojet appartenantà l'Unité de plongée de la Flotte de la Marine canadienne, et les impulsions transmises ont été enregistrées par un hydrophone déployé à l'intérieur de la barge de RDDC Atlantique. Différents types d'impulsions ont été utilisés à diverses distances. Le rapport présente certaines séries chronologiques enregistrées ainsi que les résultats du filtrage adaptatif de ces séries chronologiques avec les impulsions d'entrée (avant la compensation spectrale).

This page intentionally left blank.

Executive summary

BACKGROUND

This is the second report in a series of reports dealing with aspects of the DRDC Technology Investment Fund (TIF) project “Exploiting Ultra-Wideband and Coded Sonar Pulses”. In this report we investigate the characteristics and potential of the medium and high frequency Multi-Mode Pipe Projector (MMPP) transducers over various wide frequency bands. The very wide bandwidths allow the transducer to accurately create either very short duration pulses or complicated extended pulses such as Chirps or sequences of smaller pulses. It is hoped that the wideband capabilities of the MMPP technology will be useful in a variety of applications such as underwater communications, decoy signals, low amplitude extended sonar pulses, and target scattering. These applications have naval relevance for improved mine classification, stealthy underwater communication, torpedo jamming, and diver detection systems. In this report, we consider the performance of the system during a deployment from a small boat in Bedford Basin and transmitting various pulses to a hydrophone deployed from the DRDC Atlantic barge.

SIGNIFICANCE OF RESULTS

It is shown in this report that during a deployment in Bedford Basin, under less than favorable conditions, that various pulses could be accurately transmitted to a distant hydrophone. Using matched filtering techniques it was possible to visually detect the pulses to a range of 567 m.

FUTURE WORK

The results of the trial described in this report are encouraging. Significant transmission ranges using the MMPP projectors were obtained. However, as is discussed there were several sources of experimental uncertainty. For example, there was significant motion of the transducer during its deployment due to the wind and currents and the significant drifting of the boat. Thus the depth of the transducer and its orientation varied significantly with time, thus affecting the transmission characteristics of the transducer and the propagation loss to the hydrophone at the barge. There are certainly approaches which can be taken in future trials to control some of these uncertainties better. In the future, we would also like to consider the transmission of even more extended and complicated pulse types.

Fawcett, J., 2005. Some matched filtering experiments in Bedford Basin with the MMPP transducers. DRDC Atlantic TM 2005-133, Defence R&D Canada - Atlantic.

Sommaire

CONTEXTE

Voici le deuxième rapport d'une série portant sur divers aspects du projet du Fonds d'investissement technologique (FIT) de RDDC intitulé "Exploitation d'impulsions sonar codées à bande ultra-large ". Le présent rapport examine les caractéristiques et le potentiel des transducteurs munis d'un projecteur à tuyau multimode (MMPP) à fréquences hautes et moyennes, dans diverses bandes de fréquences larges. Les très grandes largeurs de bande permettent aux transducteurs de créer, avec précision, soit des impulsions de très courte durée, soit des impulsions étendues compliquées comme des impulsions comprimées ou des séquences d'impulsions plus courtes. On espère que les caractéristiques de large bande de la technologie MMPP s'avéreront utiles pour diverses applications, comme les communications sous-marines, l'imitation par signaux leurres, la transmission d'impulsions sonar étendues de basse amplitude et la diffusion des cibles. Du point de vue naval, ces applications pourraient améliorer les systèmes de classification des mines, de communications sous-marines furtives, de brouillage des torpilles et de détection des plongeurs. Le rapport décrit le rendement du système durant un déploiement à partir d'une petite embarcation dans le bassin de Bedford et la transmission de diverses impulsions vers un hydrophone déployé à partir de la barge de RDDC Atlantique.

PORTÉE DES RÉSULTATS

Le rapport démontre que, durant un déploiement dans le bassin de Bedford, dans des conditions moins que favorables, diverses impulsions pouvaient être transmises avec précision vers un hydrophone éloigné. Grâce à des techniques de filtrage adapté, il a été possible de détecter visuellement les impulsions jusqu'à une distance de 567 m.

RECHERCHES FUTURES

Les résultats de l'essai décrit dans le rapport sont encourageants. Les projecteurs MMPP ont permis d'atteindre des portées de transmission considérables. Il est toutefois également question de plusieurs sources d'incertitude exprimentale. Par exemple, les transducteurs se sont déplacés considérablement durant le déploiement, en raison du vent, des courants et de la dérive marquée de l'embarcation. Ainsi, la profondeur et l'orientation des transducteurs ont varié beaucoup dans le temps, ce qui a influé sur les caractéristiques de transmission des transducteurs et sur la perte de propagation vers l'hydrophone de la barge. Au cours de futurs essais, on pourrait certainement recourir à des techniques permettant de mieux maîtriser certaines de ces incertitudes. Dans l'avenir, nous aimerions aussi nous pencher sur la transmission d'impulsions de types encore plus étendus et compliqués.

Table of contents

List of figures

Acknowledgements

We would like to thank the Fleet Diving Unit Atlantic of the Canadian Navy for providing a jet boat (FDU 21 Resolute) and a driver for this trial.

This page intentionally left blank.

1 INTRODUCTION

In 2003 a TIF (Technology Investment Fund) was granted for the project “Exploiting Ultra-Wide-Band and Coded Sonar Pulses”. This project proposed using the transducer technology, Multi-Mode Pipe Projector (MMPP), developed at DRDC Atlantic [1,2] as the type of transducer for the study of various wideband applications. In particular, 3 different MMPP sizes will be considered during this TIF project. For the studies in this report, we focus on the 2 smallest transducers (high frequency (HF) and mid-frequency (MF)) which have significant output in the frequency range 20-120 kHz and 5-120 kHz respectively. The dimensions of the HF transducer are approximately, 5.3 cm high and a diameter of 3.7 cm whereas the bigger MF projector is approximately 15 cm high with a diameter of 9.5 cm. The HF transducer and its spectral characteristics were studied in detail in the DRDC Atlantic acoustic calibration tank and reported in [3]. Much of the discussion in this present report will rely on the work discussed in this reference. In particular, the various pulse types we used in the trial of this report were discussed in [3] and the method that is used to compensate the pulses input to the projector for the projector’s spectral response is described. However, the work of [3] was done under very controlled circumstances in the DRDC Atlantic tank: the water was calm, the projector and recording hydrophone were placed quite precisely along the same axis and the range was only 2 m. In this case, it was possible to transmit specified pulse types accurately and to obtain high signal-to-noise (SNR) and large time compression ratios after match-filtering the recorded time series. The question arises, however, as to how well these techniques will work in a more realistic scenario and at much longer ranges. The work of this present report is a first step in answering this question.

2 MATCHED FILTERING EXPERIMENTS

2.1 Pulse Types

In this section we describe the main pulse types we used in the trial. First, we consider a constant bandwidth pulse with centre frequency f_c and bandwidth B_f. In the time domain this Sinc pulse is given by

$$S_s(t) = \frac{sin(\pi B_f t)}{\pi B_f t} \cos(2\pi f_c t). \tag{1}$$

For very small bandwidths the signal is harmonic in nature with frequency f_c, for larger bandwidths the pulses becomes shorter and contain only a few cycles of the harmonic signal.

A simple pulse type, such as the Sinc pulse described above, can be used as the "building-block" in a sequence of pulses. In particular, we consider a sequence of Sinc pulses separated by 80 μseconds (160μ seconds for a low-frequency version of the Sinc pulse (5-30 kHz)). These pulses are then used in a sequence of ± 1 following either a 5- or 11-term Barker code [3,4]. For the HF MMPP, the Sinc pulse was centred at 65 kHz with a bandwidth of 60 kHz and 5 and 11-term Barker codes were used. For the MF MMPP, Sinc pulses were constructed for the frequency bands, 5-30 kHz and 5-95 kHz.

We also considered "Chirp" pulses, where the instantaneous frequency varied linearly over a specified band for durations of 1 and 2 msec. For the HF MMPP we considered the frequency band 35-95 kHz and for the MF MMPP we considered 1 millisecond variations of 5 to 30 kHz and 5 to 95 kHz.

As was described in [3] these desired pulses were first spectrally compensated. This was done by specifying a wideband Sinc pulse over the frequency band of interest (corresponding to a spectral value, $B(f) \equiv 1$ over the band). The recorded signal yields another spectral function $S(f)$. Defining

$$Q(f) \equiv \frac{B(f)}{S(f)}, \tag{2}$$

it is straightforward to show that for a desired signal with spectrum $\tilde{B}(f)$ (within the frequency band spanned by S(f) and B(f)), the signal input to the projector should have the input spectrum,

$$I(f) = Q(f)\tilde{B}(f). \tag{3}$$

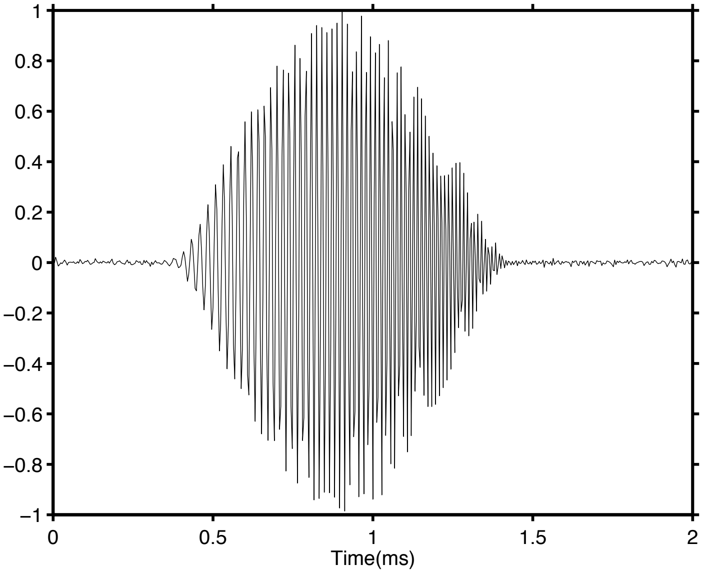

Figure 1: *A one millisecond Chirp (cosine-tapered) with frequency varying from 35 to 95 kHz (HF MMPP as measured in DRDC Atlantic acoustic calibration tank)*

In Eq.(2) we modify the division to have the form

$$Q(f) \equiv \frac{B(f)}{S(f)/|S(f)|(|S(f)|+a)}, \tag{4}$$

where a is a specified scalar (we typically use 0.05 or, in some cases with significant nulls in the spectra, 0.01). This compensation process was done using a signal recorded in the DRDC Atlantic tank at a depth of approximately 2 m, prior to the deployment in Bedford Basin. For some applications, it might be preferable to do this compensation procedure at the depth and range of a specific deployment. In Figs. 1 and 2, a 1 msec Chirp (cosine-tapered), with the frequency varying between 35- and 95-kHz, and the corresponding Fourier spectrum are shown. These are the result of using a compensated input waveform and these measurements were made in the very controlled environment of the DRDC Atlantic acoustic calibration tank.

2.2 Experimental Setup

The experiments we describe in this report took place in Bedford Basin in the vicinity of the DRDC Atlantic Barge. A Reson TC 4014 hydrophone was deployed in the tank interior to the barge at a depth of 20 m. The hydrophone signal was digitized with a 16-bit card representing the voltage range

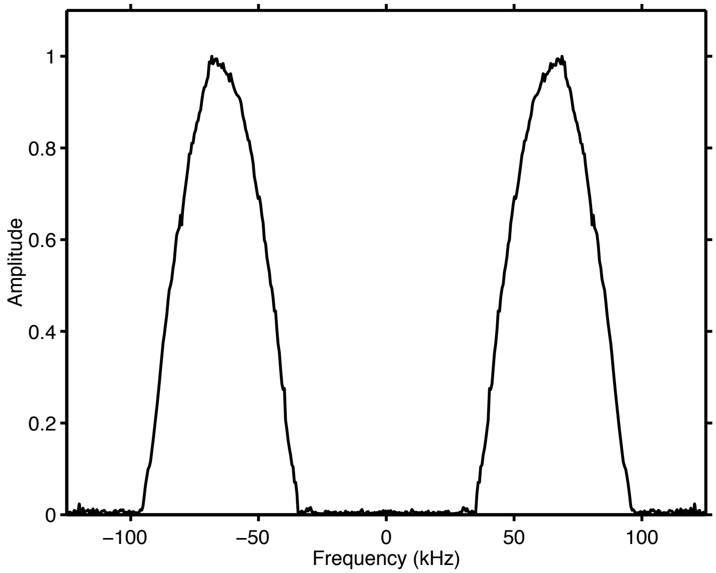

Figure 2: *The spectrum of the one millisecond Chirp (cosine-tapered) with frequency varying from 35 to 95 kHz (HF MMPP as measured in DRDC Atlantic acoustic calibration tank)*

$-0.25V$ to $0.25V$. The sampling rate was 250 kHz. The 2 MMPP projectors were deployed at different times from the back of the FDU 21 Resolute. An Instruments Inc. power amplifier was used with a peak-to-peak voltage of approximately 800 volts being supplied to the projector. This corresponds approximately to a rms level of 189 dB re 1 μPa (at 1 m) for the HF MMPP and a level of 184 dB re 1 μPa (at 1 m) for the MF MMPP. A sound speed profile was taken at the barge and is shown in Fig. 3. A ray-trace is shown for a source (or by reciprocity a receiver) in Fig.4 and the computed transmission loss (incoherent addition of ray bundles) for 50 kHz is shown in Fig.5. These computations were done using the computational code BELLHOP [5,6]. For the ray trace, the rays are limited to $\pm 10°$ from the horizontal and for the transmission loss plot rays within $\pm 15°$ are included in the computation.

These plots show that the propagation characteristics are somewhat complicated. For some source regions, one would expect multiple direct arrival ray paths. During the trial, the projector was deployed to 20 m depth. Unfortunately, there was significant wind and currents during the time of the trial, and the boat drifted considerably, resulting in the projector rising significantly above 20 m. This also means that the orientation of the projector was not vertical. As is shown in [3] the HF MMPP has a complicated vertical beampattern. The spectral compensation was done for the hydrophone in the plane of the middle slot of the projector. It was found in the beampattern

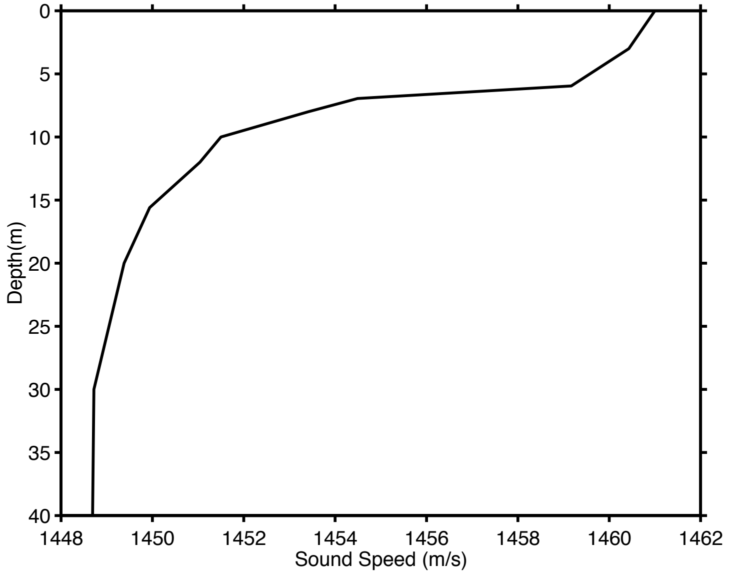

Figure 3: *Sound speed profile at DRDC Atlantic barge, April 19, 2005*

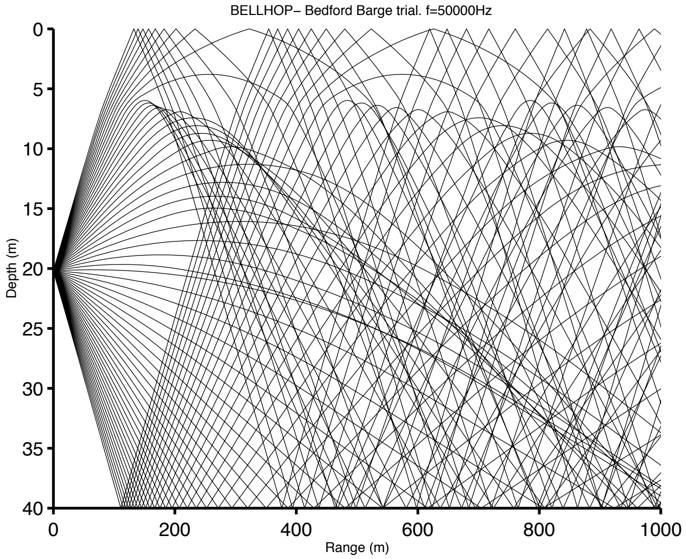

Figure 4: *Computed rays for sound speed profile and a bottom at 40 m*

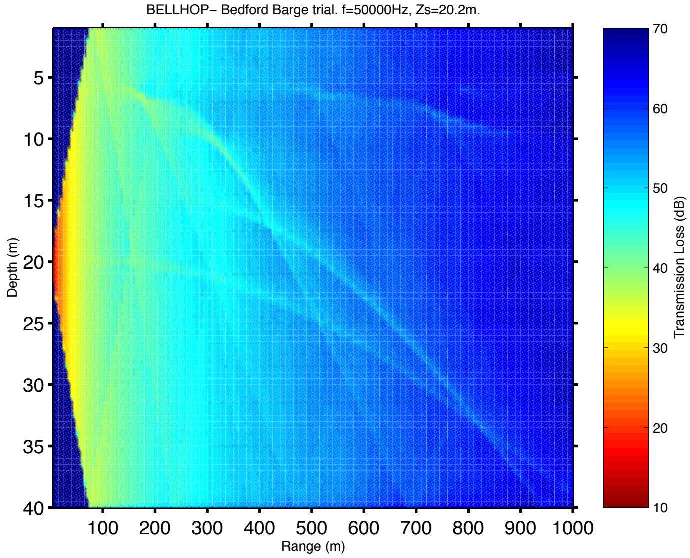

Figure 5: *Two-dimensional transmission loss (incoherent) for source at 20.2 m*

measurements for the HF MMPP that for only a few degrees away from this orientation, the spectral characteristics of the transducer changed appreciably. This is particularly true for frequencies close to 80 kHz. Thus during this trial we expect the motion and orientation of the projector to effect the received signal in terms of the amplitude of the signal (e.g.,source depth and propagation) and the spectral characteristics of the signal (e.g., the orientation of the projector is several degrees from vertical).

2.3 Experimental Data

For the first measurements of this trial, the jetboat was tied up to the landing platform of the DRDC Atlantic barge. In Fig. 6 we show a representative HF MMPP Sinc pulse that was collected. The direct arrival is evident, followed by a surface(and possibly bottom reflection) after an additional 16 msecs. Taking the source and receiver to be at 20 m depth, this corresponds to a range of approximately 21.57 m. In Fig. 7 we show from top to bottom, the recorded Sinc, 5-term Barker code, 11-term Barker code, the 1 msec Chirp and the 2 msec Chirp. These pulses are not in perfect agreement with their theoretical versions and are not quite as accurate as those obtained in the DRDC Atlantic acoustic calibration tank. However, they are good replications of the desired signals.

The boat then proceeded to deploy the HF MMPP and then the MF MMPP at a sequence of ranges. Unfortunately, the boat was significantly drifting

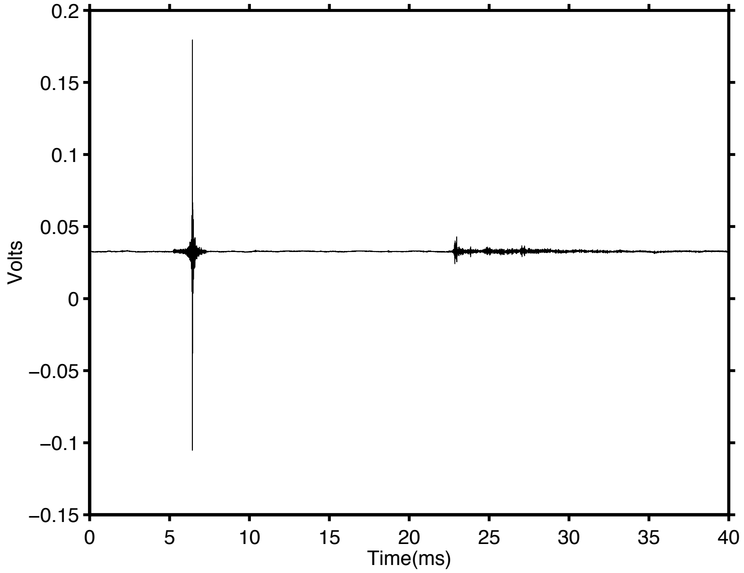

Figure 6: *A representative HF MMPP Sinc (centre frequency - 65 kHz, bandwidth - 60 kHz) pulse for jetboat tied up at a range of approximately 21 m. The direct arrival is first seen and then subsequent arrivals from the upper surface and seabed*

during the times of deployment and the ranges changed considerably for the different pulse types. Thus, we have the pulse types at differing ranges varying between 55 and 613 m. The pulses were transmitted at the rate of 10 Hz and the recorded time series files were 1 second in length. Thus one would expect to see or detect 10 pulses in each file. In a sequence of figures, starting with Fig. 8, we show the time series (after subtracting the mean), the matched filtered amplitude (the amplitude of the complex envelope of the cross-correlation), and a zoom around one of the matched filtered peaks for a selection of some of the pulses and ranges for the HF and MF MMPPs. In Fig. 8 we show the 1 msec (frequency varying from 35 to 95 kHz) Chirp (HF MMPP) at a range of approximately 260 m. The ranges quoted in this report were obtained by using the GPS position of the boat (for one of the ping times) and the estimated position of the hydrophone on a georeferenced sidescan sonar image of the DRDC Atlantic barge. These ranges should be accurate to a few metres. In this case, the signal can be seen in the original time series; however, the matched filtering does significantly increase the signal-to-noise ratio (SNR). For example, the ratio of the peak value in the top plot of Fig. 8 to the rms amplitude is a ratio of about 9.78 whereas for the matched filtered output the ratio is approximately 76.5 or an gain ratio of 7.82. This gain is more than the predicted gain of $.707 \times \sqrt{60} = 5.47$ (here, the factor 0.707 is to account for the cosine tapering used, the factor 60 is the time-bandwidth

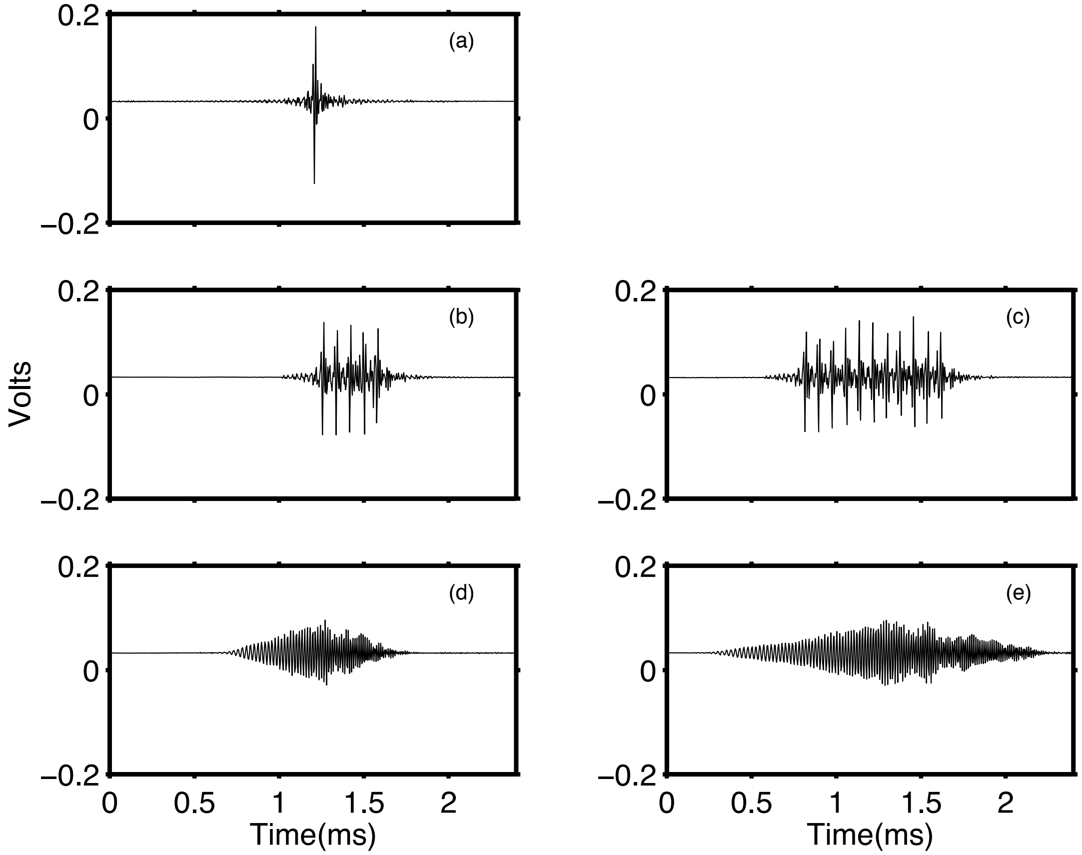

Figure 7: *Representative direct pulses: (a) Sinc, (b) 5-term Barker, (c) 11-term Barker, (d) 1 ms Chirp and (e) 2 msec Chirp for HF MMPP, boat tied up. the range is approximately 22 m. The bandwidth of all the pulse types is approximately 60 kHz.*

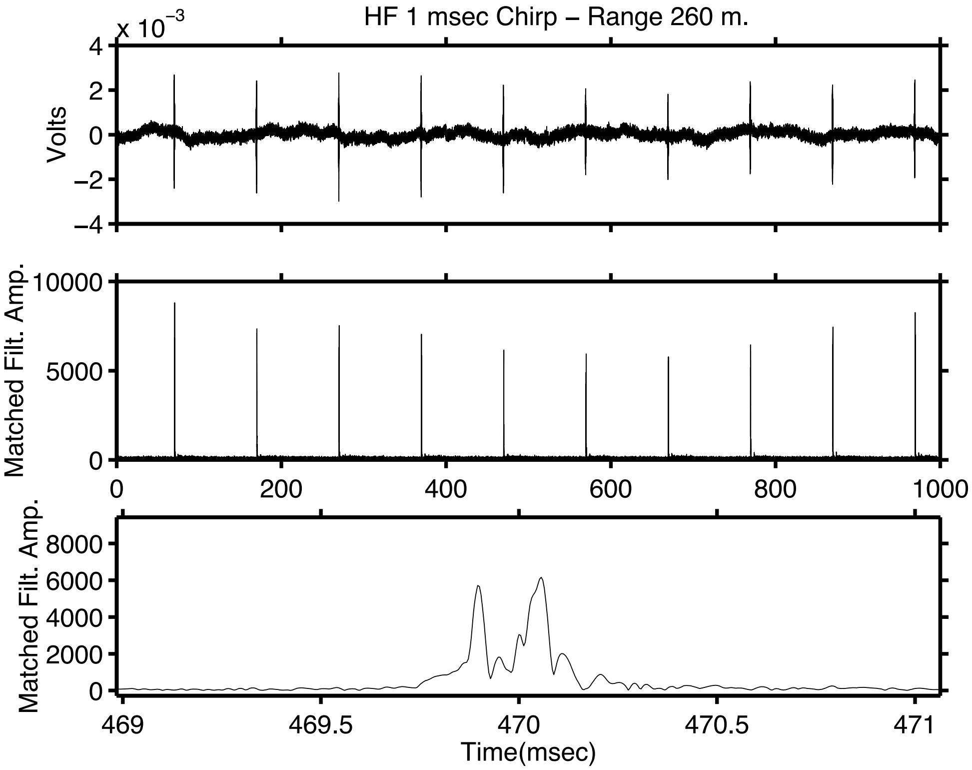

Figure 8: *One of the pings recorded (mean subtracted out) for a one millisecond cosine-tapered Chirp pulse (35-95 kHz) at a range of 260 m, the corresponding matched filtered response, and a zoom of one of the matched filtered peaks.*

product, and the square root is used since we are considering amplitude). One reason for this maybe that the background noise in the original time series is not truly random, containing systematic variations. In Fig. 9 we show a two-dimensional time frequency plot of one of the received pings from Fig. 8 (using the MATLAB function, SPECGRAM). The linear time-frequency variation is evident. In Fig. 10 we show the received and matched filtered signals for the 11-term Barker code at a range of 55 m. Here, as one would expect the signal is visually detectable. The matched filtered results show the very nice cross-correlation properties of a Barker code. There is the main cross-correlation peak and smaller values regularly spaced at 160μseconds (because of the property of the Barker code, the cross-correlation values at every second multiple of the individual pulse spacing, 80μseconds, is zero).

The results shown so far have been for the high-frequency MMPP. We now show two results for the midfrequency (MF) MMPP. As discussed we considered 2 frequency ranges for this MMPP, 5-30 kHz and 5-95 kHz. The results shown below are for the lower frequency band. We did record pulses for the

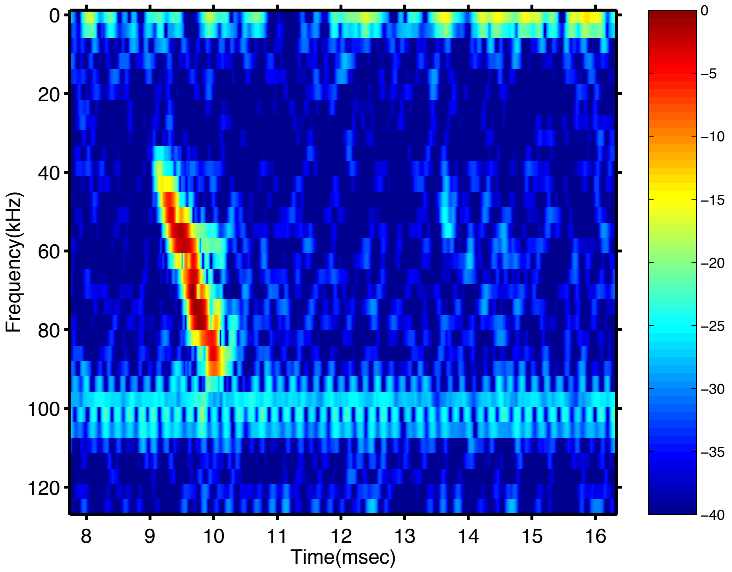

Figure 9: *Time-frequency (using moving 128-point FFT window) plot of received signal for one of the pulses of Fig. 8. The values have been normalized so that the peak power is unity (0 dB)*

larger bandwidth but there are indications from the Chirps that perhaps the power supply was being overdriven, as the time/frequency response had an extended time duration at some frequencies. In Fig. 11 we show the results for a 11 term barker code composed of Sinc functions (5-30 kHz) with a 160μsecond separation at a range of 317 m. As can be seen, the matched filtering has been very effective in increasing the SNR of the output signal. We now consider a one millisecond Chirp and a range of 196 m. In Fig. 12 we show the 3 time series and in Fig. 13 the time/frequency plot corresponding to one of the pulses. In the matched filtered results and in the time/frequency response two arrivals separated by approximately one millisecond are evident. This is consistent with the ray diagram of Fig. 4 for the projector being at depth of approximately 8 m. There are two direct paths which are separated by about one millisecond in travel time. Also, this is an area near a ray caustic and hence the amplitude of the received signal should be relatively high. As we did for the results of Fig. 8 we can compute the gain due to the matched filtering and in this case find it to be 4.85 which exceeds the predicted gain of 3.53 ($0.707 \times \sqrt{25}$, the factor 0.707 is for the cosine-tapering and 25 is the time-bandwidth product).

For the next 2 figures, we return to the HF MMPP. In Fig. 14 we show the results for the 11-term Barker Code at a range of 456 m. As can be seen, the original time series is very weak and seems to have rather strange jumps in

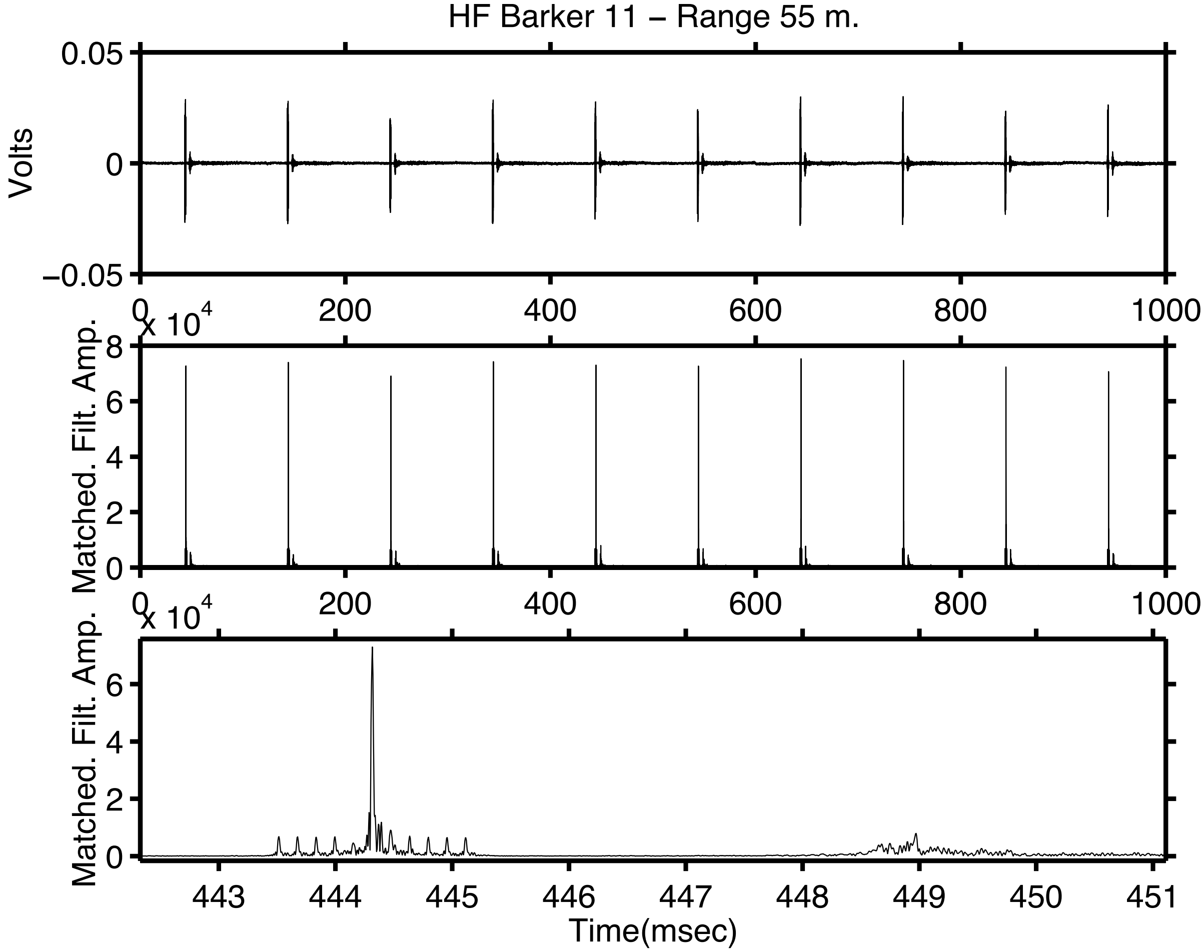

Figure 10: *One of the pings recorded (mean subtracted out) for the 11 term Barker code (composed of a sequence of 60 kHz bandwidth Sinc pulses) at a range of 55 m, the corresponding matched filtered response, and a zoom of one of the matched filtered peaks.*

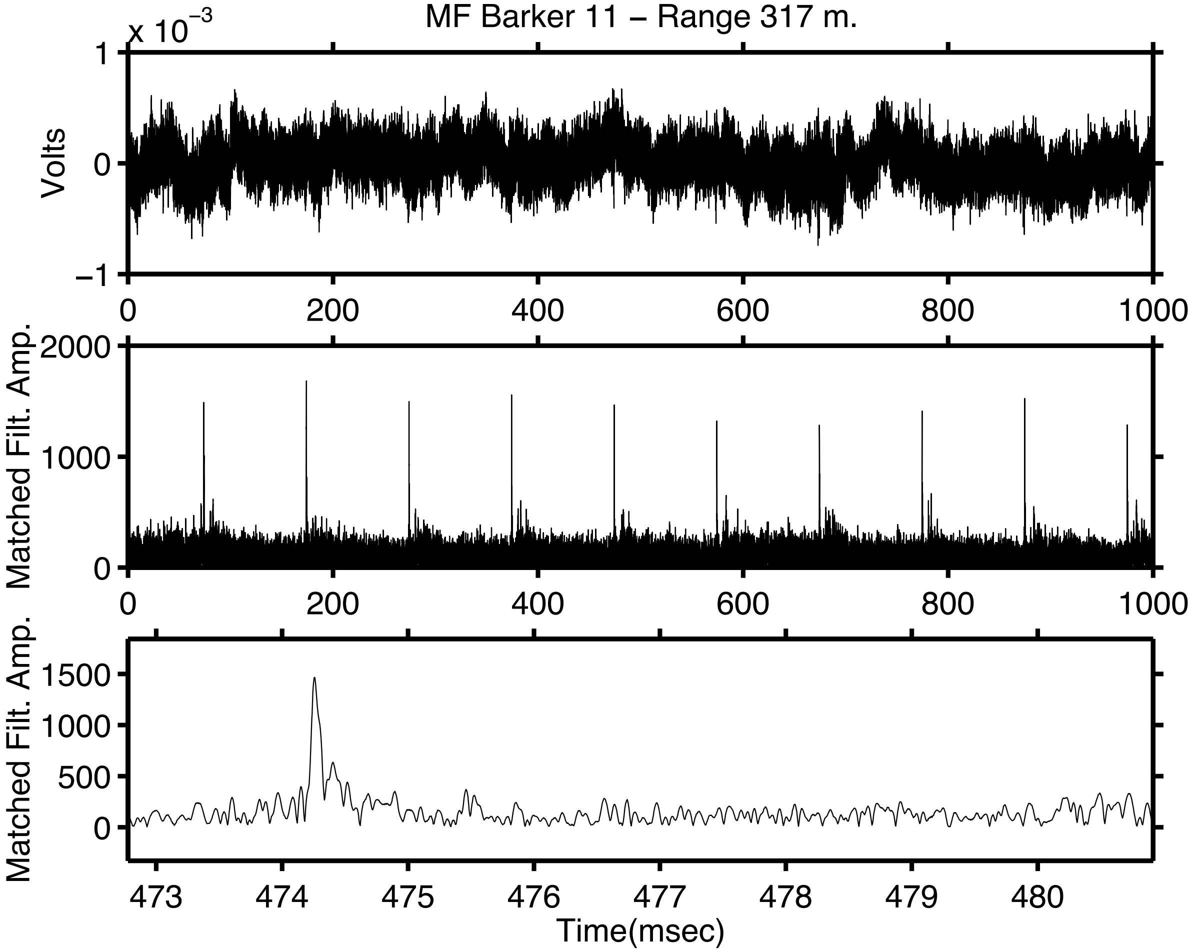

Figure 11: *One of the pings recorded (mean subtracted out) for the 11 term Barker code (composed of a sequence of 25 kHz bandwidth Sinc pulses, MF MMPP) with the MF MMPP at a range of 317 m, the corresponding matched filtered response, and a zoom of one of the matched filtered peaks.*

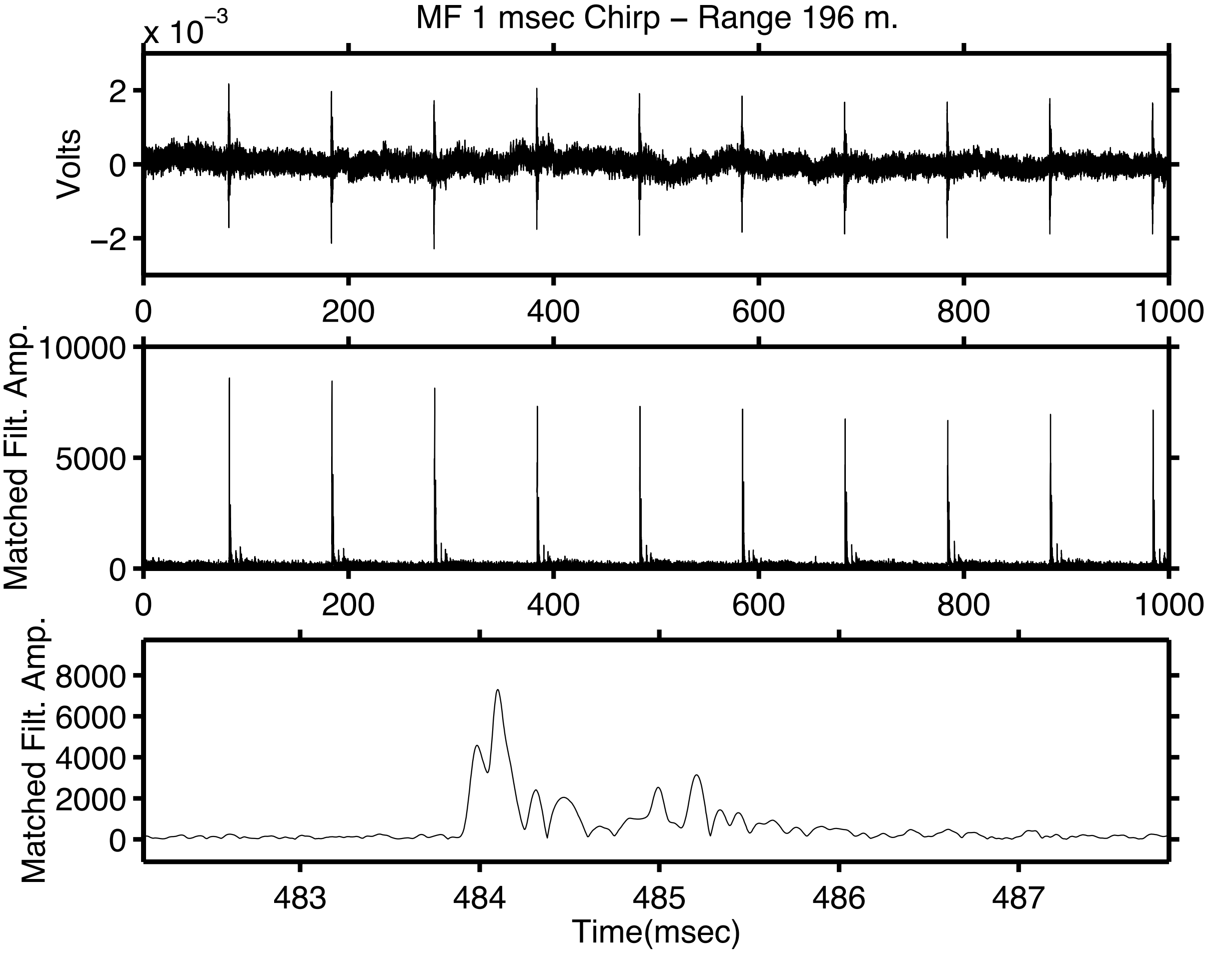

Figure 12: *One of the pings recorded (mean subtracted out) for a one millisecond cosine-tapered Chirp pulse (5-30 kHz, MF MMPP) at a range of 196 m, the corresponding matched filtered response, and a zoom of one of the matched filtered peaks.*

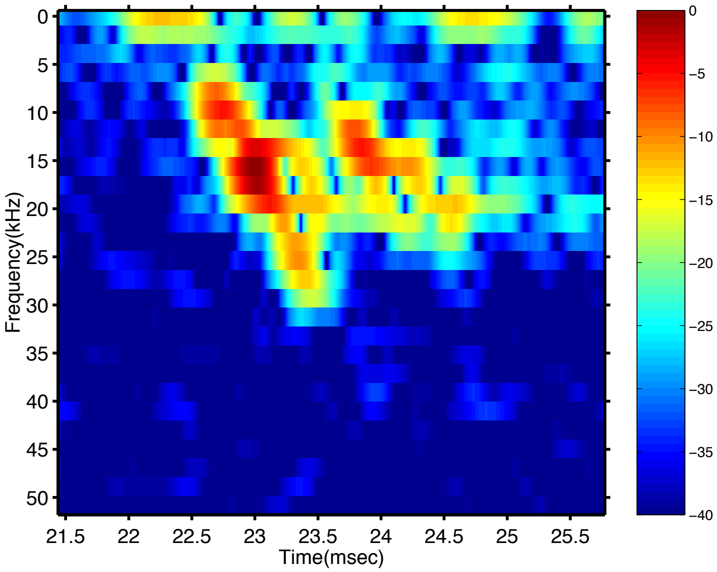

Figure 13: *Time-frequency (using moving 128-point FFT window) plot of received signal for one of the pulses of Fig. 12.*

voltage from time to time. However, the matched filtered results show strong peaks with the indication of a later multipath arrival (approximately 4 msecs after the first). In Fig. 15 we show the results for the 2 msec Chirp at a range of approximately 573 m (this is the longest range we considered) . As can be seen, the arrivals can be weakly seen in the matched filtered time series. However, some of the arrivals appear more strongly than others and the ping shown is, in fact, one of the better ones. Thus, at this range and pulse type, the ability to reliably visually detect the pulse is becoming borderline.

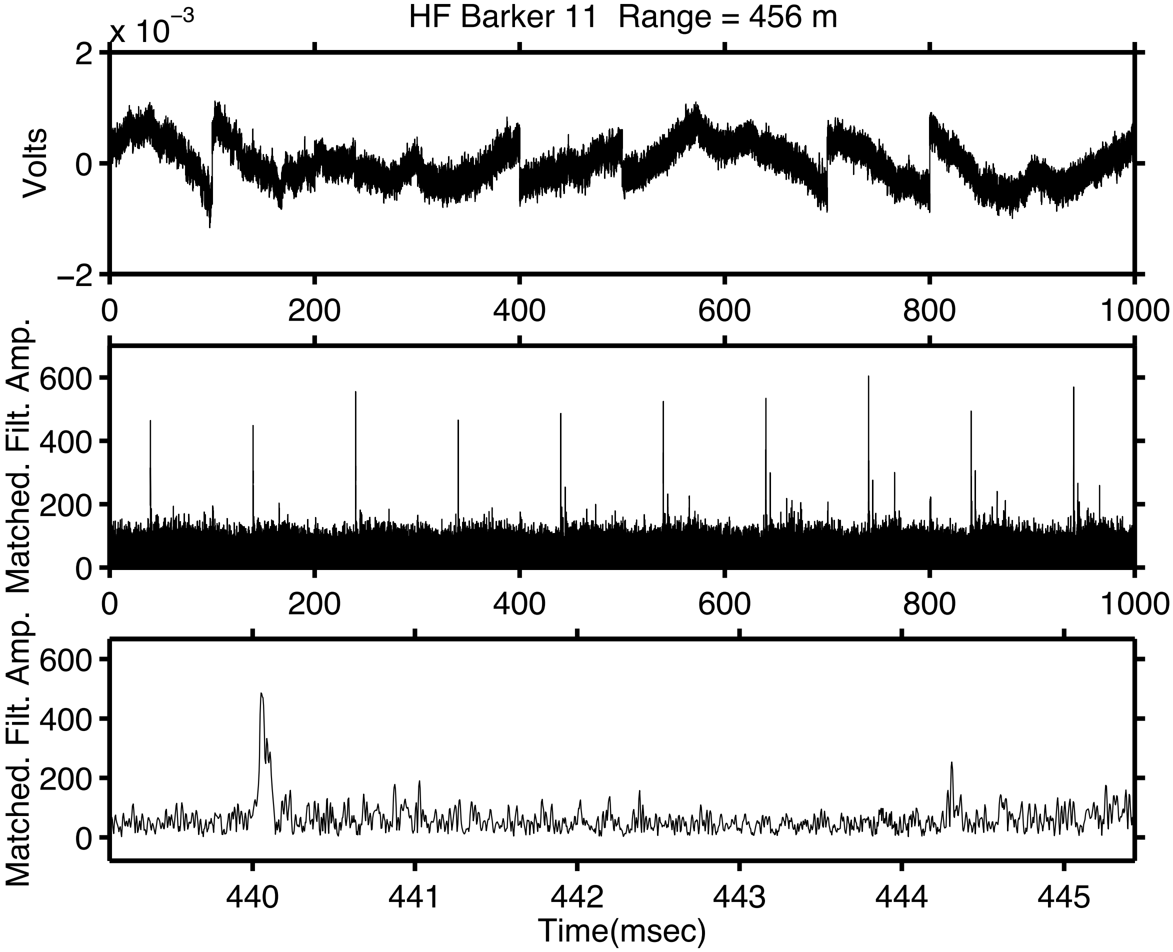

Figure 14: *One of the pings recorded (mean subtracted out) for the 11 term Barker code (composed of a sequence of 60 kHz bandwidth Sinc pulses) at a range of 456 m, the corresponding matched filtered response, and a zoom of one of the matched filtered peaks.*

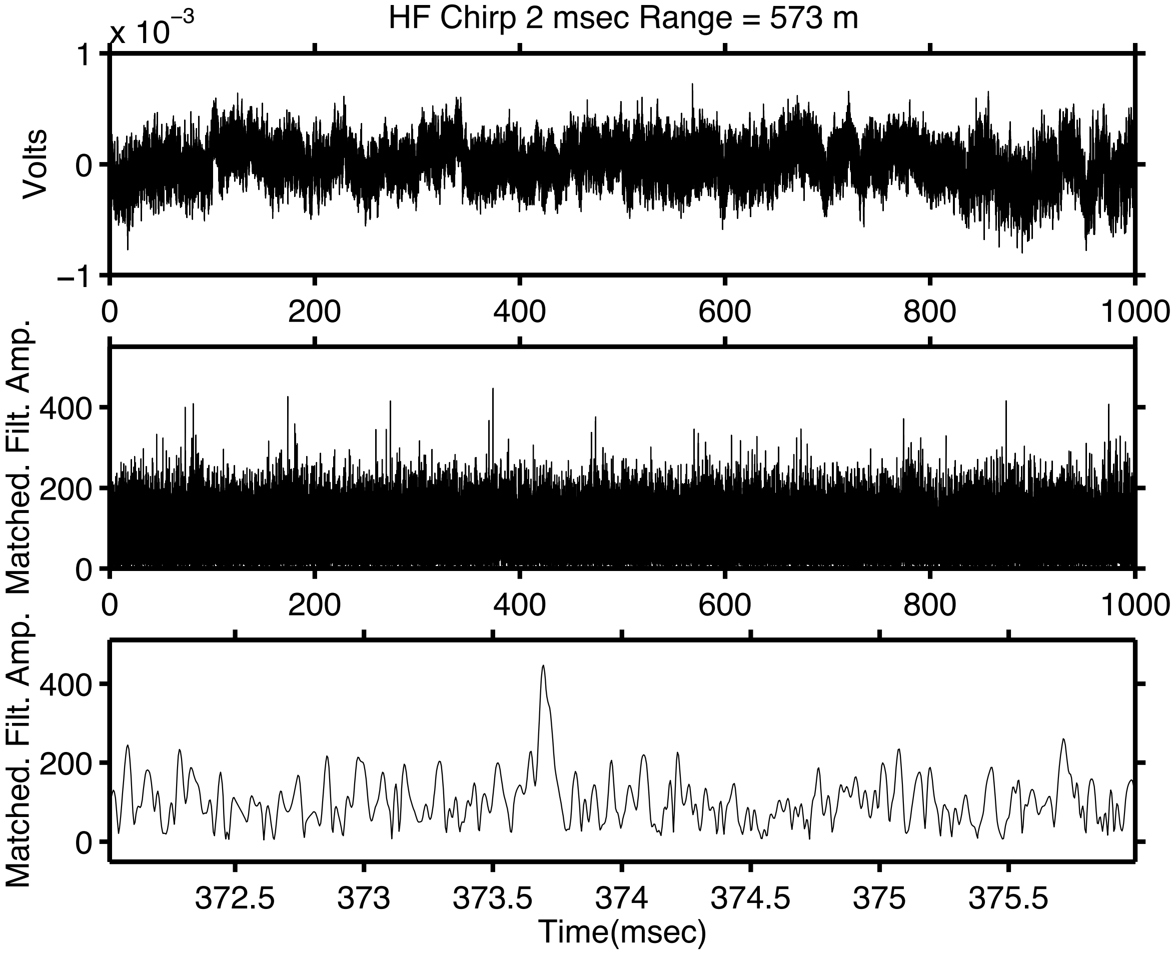

Figure 15: *One of the pings recorded (mean subtracted out) for a two millisecond cosine-tapered Chirp pulse (35-95 kHz) at a range of 573 m, the corresponding matched filtered response, and a zoom of one of the matched filtered peaks.*

3 DISCUSSION OF RESULTS

In this report we have shown that the HF and MF MMPP transducers can transmit specified pulse types over significant ranges. At 450 m range, the transmissions could be easily seen in the matched filtered time series for the 11 term Barker code (HF MMPP) while the original timeseries was not visually evident at all. At 573 m range, for a 2 msec Chirp, the arrivals in the matched filtered output were weakly observable (some times easily, sometimes not observable). The 5-30 kHz pulses of the MF MMPP also appeared promising.

One can, of course, increase the transmission ranges of the projectors by increasing their output power. For example, we could use 2 HF MMP transducers or for the MF MMPP the voltage could be increased significantly. It is also known that these projectors have a complicated vertical beam pattern. The compensated waveforms input to the projector were computed using recorded signals with the projector and receiver vertically aligned. At some frequency ranges, the vertical beampattern (and hence the compensation for wideband input pulses) is quite sensitive to vertical misalignment. Thus, we expect that during this trial, the matched filtering was likely suboptimal in some cases due to the projector being vertically tilted. It is expected that the matched-filtering results could be improved (and hence also longer ranges could be achieved) by deploying the projectors in such a way that they remain vertical. This could be accomplished by more rigidly deploying the projectors or by using a suitable towfish.

From Fig. 4, it can be seen that if we wish to obtain strong direct arrival paths, then for ranges greater than about 500 m it may be advantageous to lower the projector below 20 m (for the receiver at 20 m). Also, in the future, we would like to try longer pulses such as M-sequences and hopefully increase the matched filtering gains even more. The recording system seemed to have some problems: for example, a voltage bias which was significant for low amplitude signals. For future trials, we hope to use our newly developed 24-bit recording system.

References

1. C.J. Purcell, and R. Fleming, *Multi-Mode Pipe Projector*, US Patent 6,584,039 (2003)

2. R. Fleming, “High frequency multi-mode pipe projector”, DRDC-Atlantic TM 2003-218, November 2003

3. J.Fawcett, J. Sildam, T.Miller, R.Fleming, and M. Trevorrow, “Broadband pulse synthesis with the high frequency Multi-Mode Pipe Projector”, DRDC Atlantic TM 2005-022 (2005).

4. M. Trevorrow and D. Farmer, “The use of Barker Codes in Doppler sonar measurements”, Journal of Atmospheric and Oceanic Technology, Vol.9, No.5, October 1992.

5. M.B. Porter and H.P. Bucker, “Gaussian beam tracing for computing ocean acoustic fields”, J. Acoust. Soc. Am., **82**, pp.1349–1359 (1987).

6. A. Duncan, Acoustics Toolbox/MATLAB front end, http://www.curtin.edu.au/curtin/centre/cmst/products/actoolbox/

Distribution List

Internal Distribution

David Hopkin,
Mine and Torpedo Defence Group

Mark Trevorrow,
Mine and Torpedo Defence Group

Anna Crawford,
Mine and Torpedo Defence Group

Isaias Peraza,
Mine and Torpedo Defence Group

Juri Sildam,
Mine and Torpedo Defence Group

Vance Crowe,
Mine and Torpedo Defence Group

Mark O'Connor,
Mine and Torpedo Defence Group

Mark Rowsome,
Mine and Torpedo Defence Group

John Fawcett,
Mine and Torpedo Defence Group

Art Collier,
Mine and Torpedo Defence Group

Chris Purcell,
Sensors and Actuators Group

Garry Heard,
Rapidly Deployable Systems Group

Brian Maranda,
Sonar Signal Processing Group

Library (5)

External Distribution

NDHQ/DRDKIM

DOCUMENT CONTROL DATA

(Security classification of title, body of abstract and indexing annotation must be entered when the overall document is classified)

1. ORIGINATOR (the name and address of the organization preparing the document. Organizations for whom the document was prepared, e.g. Centre sponsoring a contractor's report, or tasking agency, are entered in section 8.)

Defence R&D Canada – Atlantic, PO Box 1012,
Dartmouth, NS B2Y 3Z7

2. SECURITY CLASSIFICATION (overall security classification of the document including special warning terms if applicable).

UNCLASSIFIED

3. TITLE (the complete document title as indicated on the title page. Its classification should be indicated by the appropriate abbreviation (S,C,R or U) in parentheses after the title).

Some matched filtering experiments in Bedford Basin with the MMPP transducers

4. AUTHORS (Last name, first name, middle initial. If military, show rank, e.g. Doe, Maj. John E.)

John Fawcett, Juri Sildam, V. Crowe, Terry Miller, Mark O'Connor and Mark Rowsome

5. DATE OF PUBLICATION (month and year of publication of document)

July 2005

6a. NO. OF PAGES (total containing information Include Annexes, Appendices, etc).

18 (approx.)

6b. NO. OF REFS (total cited in document)

6

7. DESCRIPTIVE NOTES (the category of the document, e.g. technical report, technical note or memorandum. If appropriate, enter the type of report, e.g. interim, progress, summary, annual or final. Give the inclusive dates when a specific reporting period is covered).

Technical Memorandum

8. SPONSORING ACTIVITY (the name of the department project office or laboratory sponsoring the research and development. Include address).

Defence R&D Canada – Atlantic
PO Box 1012
Dartmouth, NS, Canada B2Y 3Z7

9a. PROJECT OR GRANT NO. (if appropriate, the applicable research and development project or grant number under which the document was written. Please specify whether project or grant).

11CY04

9b. CONTRACT NO. (if appropriate, the applicable number under which the document was written).

10a ORIGINATOR'S DOCUMENT NUMBER (the official document number by which the document is identified by the originating activity. This number must be unique to this document.)

DRDC Atlantic TM 2005-133

10b OTHER DOCUMENT NOs. (Any other numbers which may be assigned this document either by the originator or by the sponsor.)

11. DOCUMENT AVAILABILITY (any limitations on further dissemination of the document, other than those imposed by security classification)

(X) Unlimited distribution
(   ) Defence departments and defence contractors; further distribution only as approved
(   ) Defence departments and Canadian defence contractors; further distribution only as approved
(   ) Government departments and agencies; further distribution only as approved
(   ) Defence departments; further distribution only as approved
(   ) Other (please specify)

12. DOCUMENT ANNOUNCEMENT (any limitation to the bibliographic announcement of this document. This will normally correspond to the Document Availability (11). However, where further distribution (beyond the audience specified in (11) is possible, a wider announcement audience may be selected).

13. ABSTRACT (a brief and factual summary of the document. It may also appear elsewhere in the body of the document itself. It is highly desirable that the abstract of classified documents be unclassified. Each paragraph of the abstract shall begin with an indication of the security classification of the information in the paragraph (unless the document itself is unclassified) represented as (S), (C), (R), or (U). It is not necessary to include here abstracts in both official languages unless the text is bilingual).

In this report we describe experiments carried out in Bedford Basin, Halifax near the DRDC Atlantic barge. The high and medium frequency Multi-Mode Pipe Projector transducers were deployed from a Canadian Navy Fleet Diving Unit jetboat and the transmitted pulses recorded by a hydrophone deployed within the DRDC Atlantic barge. A variety of different pulses types were used from various ranges. Some of the recorded time series are presented in this report as well as the results of match filtering these time series with the input (before spectral compensation) pulses.

14. KEYWORDS, DESCRIPTORS or IDENTIFIERS (technically meaningful terms or short phrases that characterize a document and could be helpful in cataloguing the document. They should be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location may also be included. If possible keywords should be selected from a published thesaurus. e.g. Thesaurus of Engineering and Scientific Terms (TEST) and that thesaurus-identified. If it not possible to select indexing terms which are Unclassified, the classification of each should be indicated as with the title).

broadband, matched filtering, transducer

Defence R&D Canada

Canada's leader in defence
and National Security
Science and Technology

R & D pour la défense Canada

Chef de file au Canada en matière
de science et de technologie pour
la défense et la sécurité nationale

DEFENCE DÉFENSE

www.drdc-rddc.gc.ca