PhD Open Days

Spiral Acoustic Fields: A Breakthrough Path to Underwater GPS

Electrical and Computer Engineering

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Background

Spiral fields exhibit a linear phase shift relative to the bearing angle, enabling the calculation of the transmitted sound's bearing. A **spiral source**, an **underwater transducer**, can generate both **circular and spiral fields**. With these two field types, it becomes possible to perform **underwater localization** by determining both range and azimuth values.

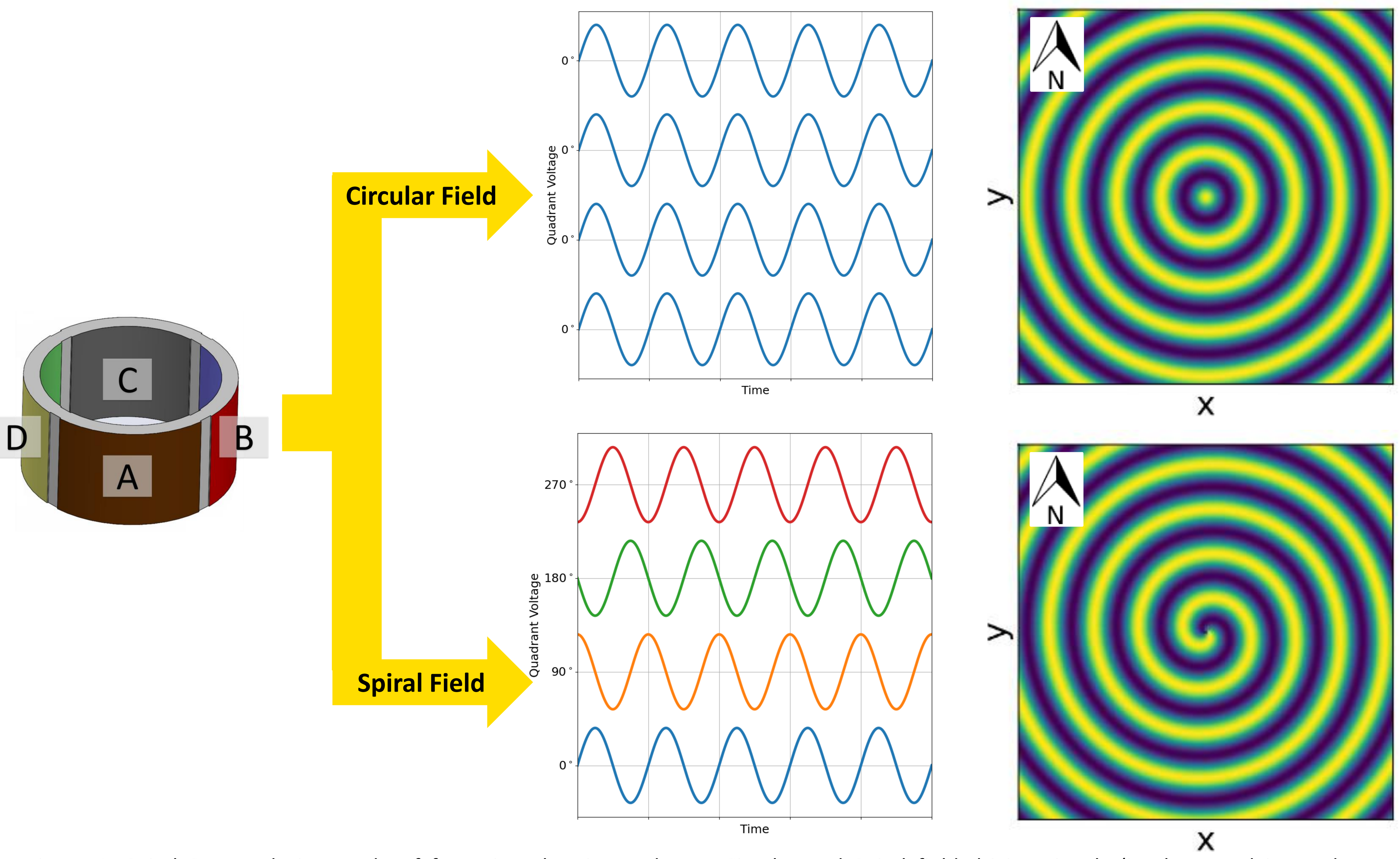

Figure 1: Spiral Source design made of four piezoelectric quadrants, Circular and Spiral field driving signals (in-phase and in-quadrature, respectively), and the 2D representation of the fields.

The use of spiral fields in underwater devices **eliminates the need for triangulation**, reducing the number of transmitters and receivers required for localization. This acoustic localization system can **lower the cost of underwater vehicles** by simplifying their acoustic systems.

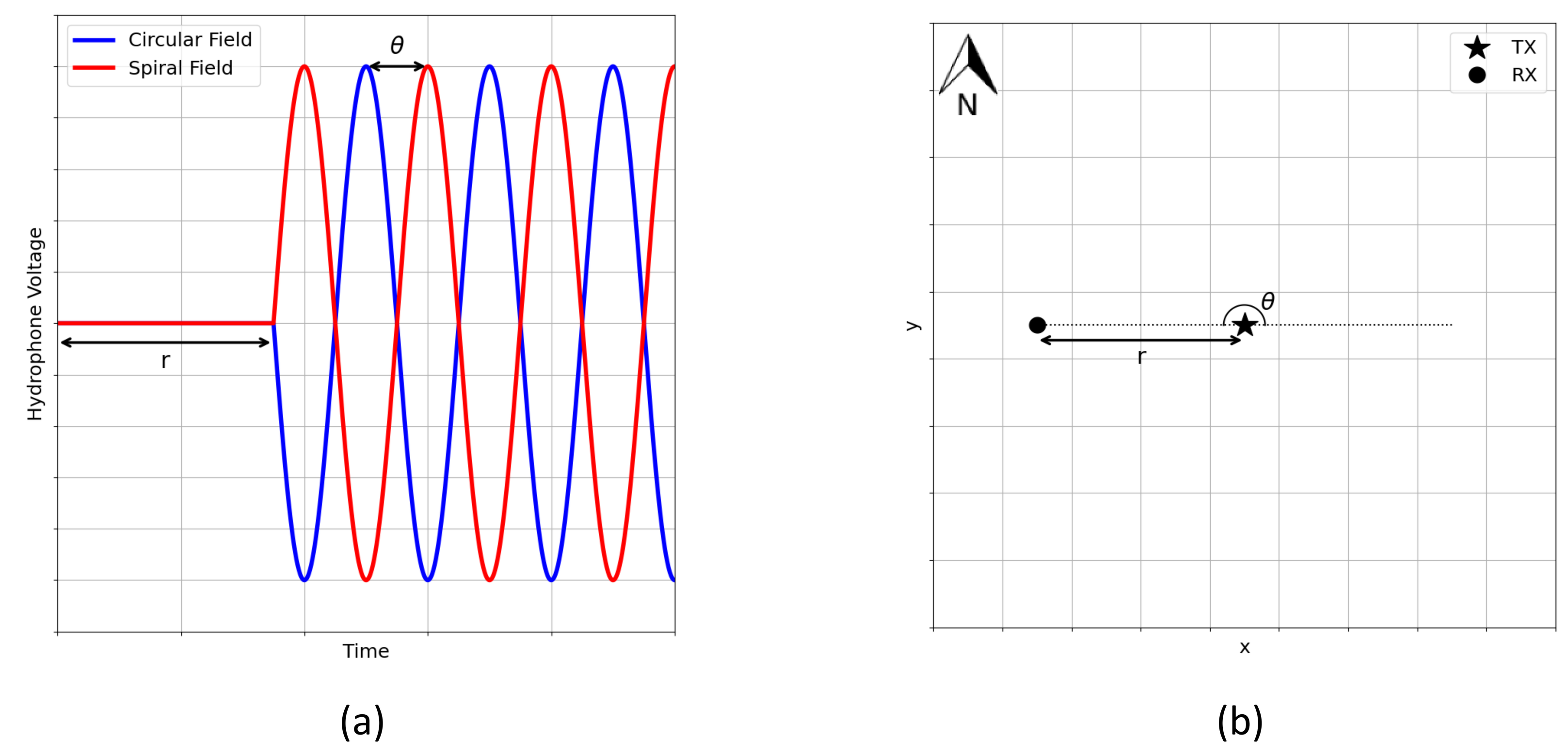

Figure 2: Spiral Field Localization Method. (a) Received signals with the range, r, and azimuth, θ, representations: the direction of the acoustic source is determined by the phase difference between the two fields, and the range is estimated using the time of flight. (b) 2D representation of the range and azimuth based on the TX and RX positions.

Spiral Source Prototypes

The **initial prototype** was designed to generate spiral fields within the frequency range of 50 to 70 kHz. Subsequently, a **second prototype** was developed to operate at **lower frequencies**, between 20 and 25 kHz. This reduction in operating frequency minimized sound attenuation in water, enabling the system to function effectively **over greater distances**.

The calibration of the prototype was conducted in a pool using a stepper motor, which allowed for the acquisition of acoustic signals from the spiral source at various bearing angles. The calibration results demonstrated a relatively constant radiation pattern across the azimuth and confirmed that the system behaved linearly.

Additionally, the **signal generation and amplification system** required for sea operation was successfully developed.

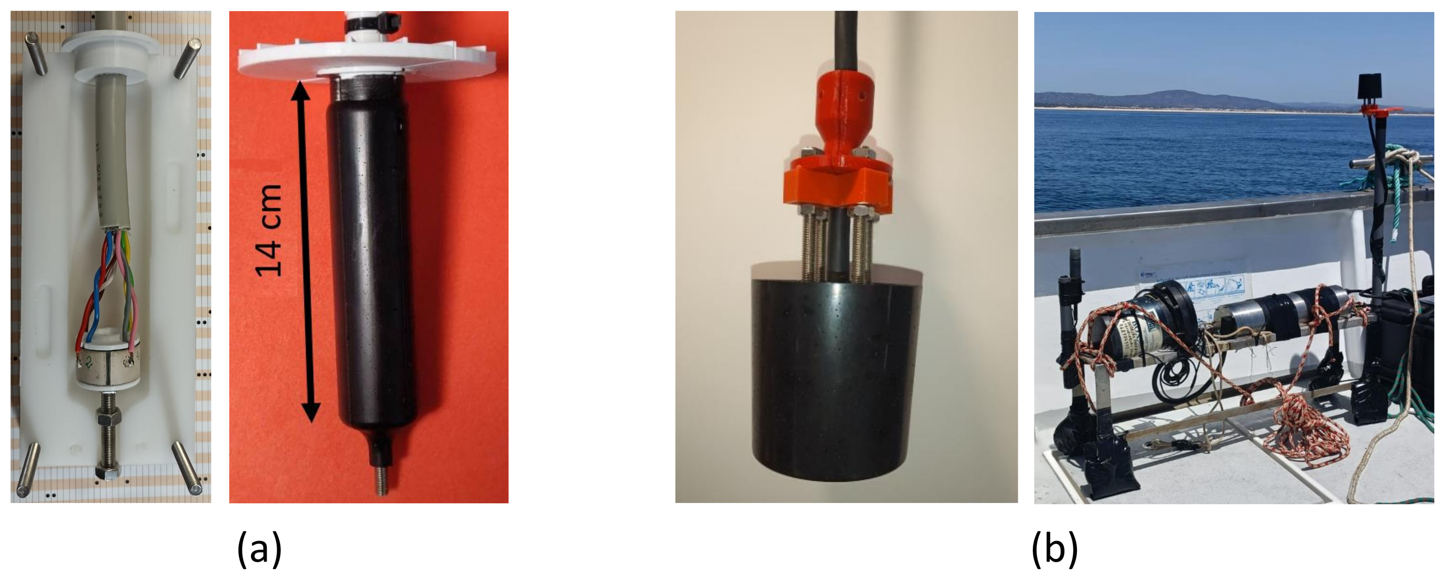

Figure 3: Developed Spiral Source Prototypes: (a) high frequency prototype before and after potting, and (b) low frequency prototype and the secondary devices for sea operation.

Spiral Beacon Underwater Localization

An experiment was carried out off the coast of Olhão, Portugal, where the spiral source was anchored 30 meters deep. The experiment vessel traveled up to 1500 meters away from the beacon and a hydrophone recorded the acoustic signals. The acoustic localization was then compared with the location obtained via GPS. The results show that the developed system **can locate a mobile hydrophone in a maritime environment up to 1500 meters**, with a mean absolute azimuth error of 7 degrees.

Figure 4: Vessel used on the localization experiment.

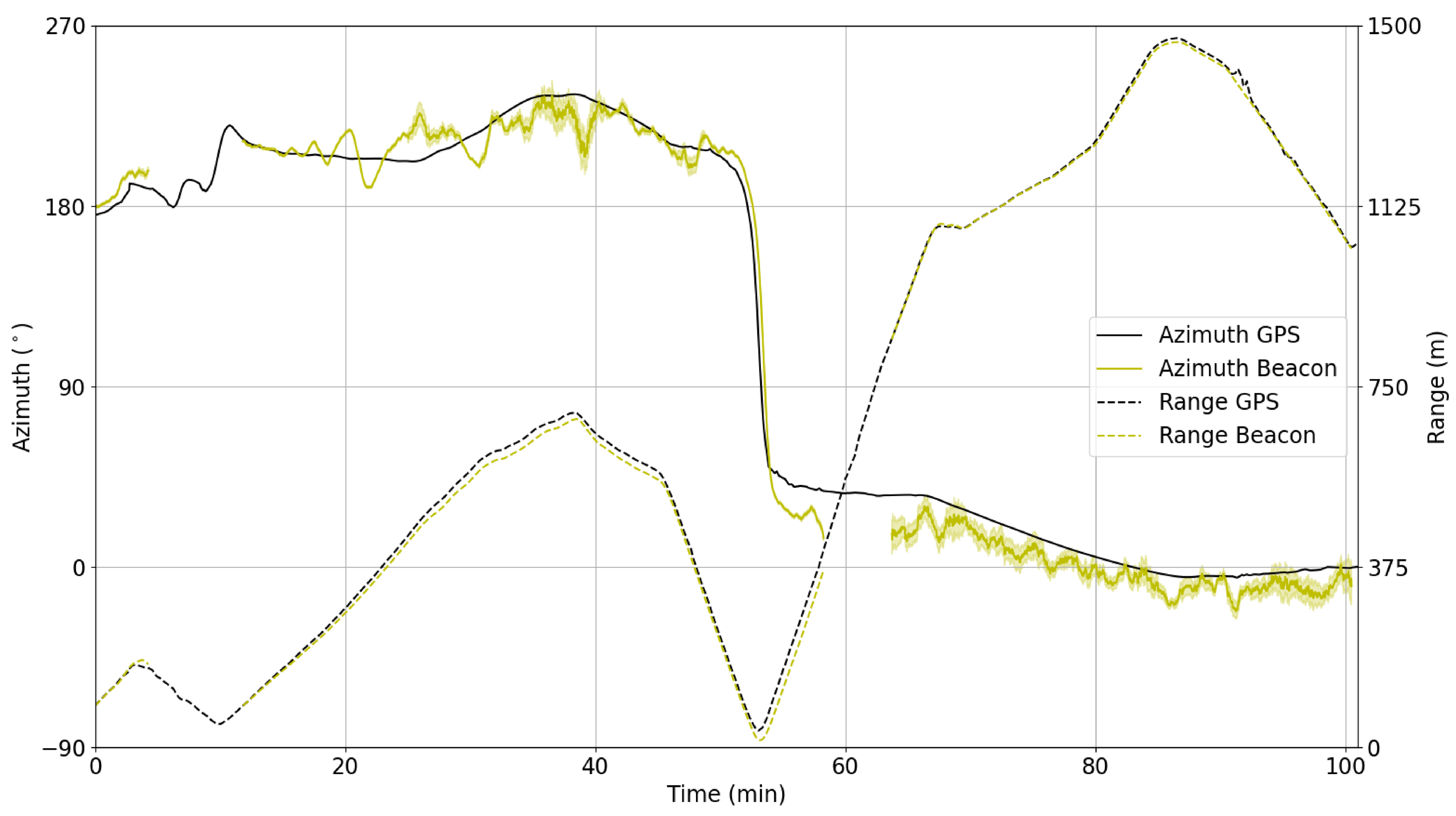

Figure 5: Azimuth and range plot over time for the GPS and Beacon localization, in black and yellow, respectively.

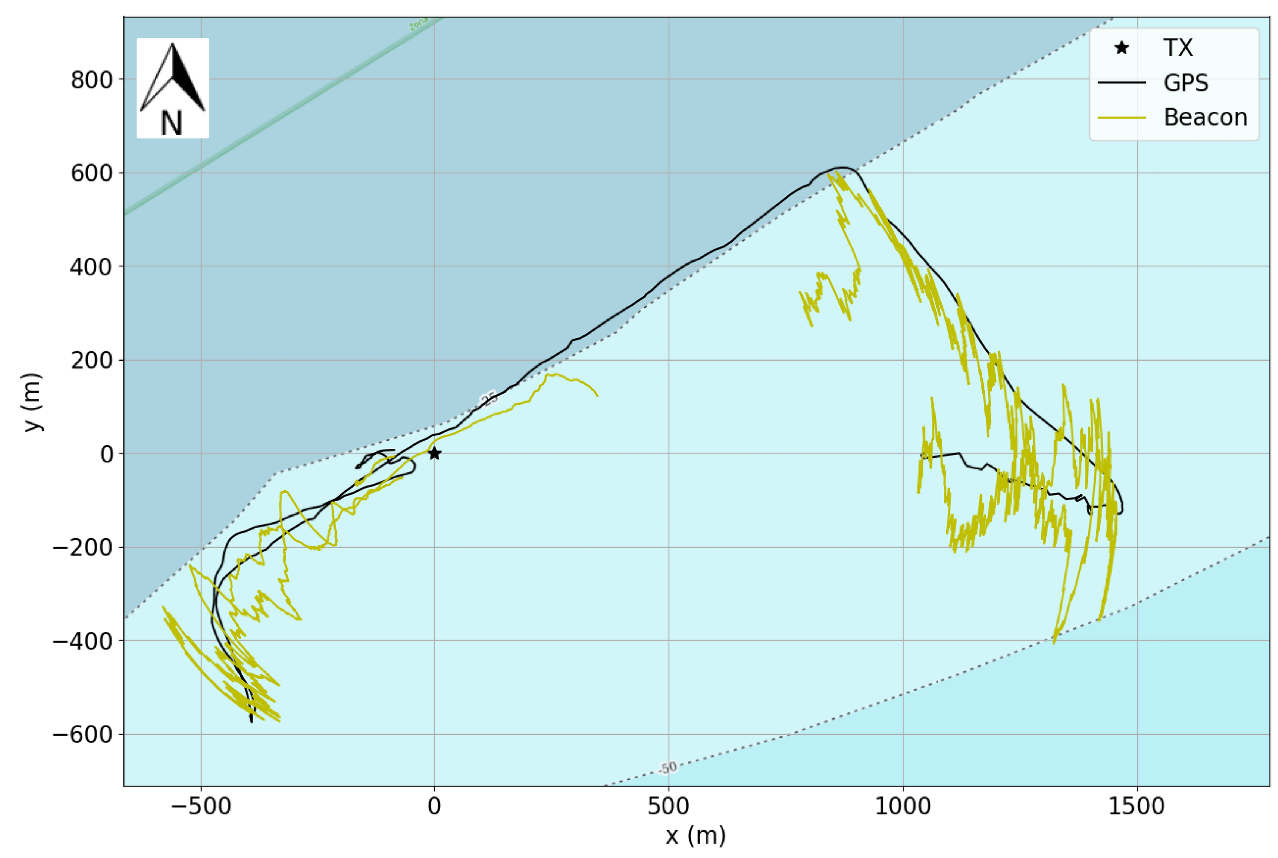

Figure 6: 2D representation of the GPS and the Beacon localization, in black and yellow, respectively.

Conclusions and Future Work

Underwater Localization using spiral fields is an **alternative to traditional acoustic methods** that presents **promising results on maritime environments**. The developed method still presents some limitations, namely the **variability of azimuth estimation**, which is related to the sensitivity to the multipath of the acoustic channel. This aspect must be improved in the future.

[1] R. S. Viegas, F. Zabel, and A. Silva, “In-Lab Demonstration of an Underwater Acoustic Spiral Source”, Sensors, vol. 23, no. 10. MDPI AG, p. 4931, May 20, 2023.
[2] R. S. Viegas, F. Zabel, J. Gomes, and A. Silva, “Spiral Beacon Calibration and Experiments for Underwater Localization”, OCEANS 2024 - Singapore. IEEE, Apr. 17, 2024.
[3] R. S. Viegas, F. Zabel, A. Silva, and J. Gomes, “Underwater Localization using Time and Frequency Multiplexing of Circular and Spiral Acoustic Fields”, UCOMMS 2024. IEEE, Sep. 5, 2024.

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