

COMMENTARY

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Compatibility in acoustic telemetry

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Abstract

Acoustic telemetry is widely used to investigate aquatic animal movement. Pulse position modulation (PPM) is an acoustic telemetry method that allows multiple unique identification codes to be transmitted at a single acoustic frequency, typically in the 69 kHz range. However, because the potential number of unique identification codes (i.e. tags) is ultimately limited by the number of pulses in the PPM signal, this poses a practical limitation. In addition, different manufacturers have developed different approaches to encoding the transmitted data, hampering compatibility across brands. A lack of broad compatibility across telemetry systems restricts users to a single manufacturer and operating system, reduces market competition and limits innovation. As the aquatic animal tracking research community organises towards networks of devices and data, incompatibility becomes more problematic and jeopardizes the unique scientific benefits offered by the networking approach. Here, we make a plea for collaboration among the manufacturers globally and propose a set of open protocols to ensure equipment interoperability as a medium-term solution.

Keywords: Acoustic telemetry, Equipment interoperability, Open Protocol, Pulse position modulation

Technical background in acoustic telemetry

Animal tracking is increasingly used worldwide to investigate the behaviour of aquatic animals [1, 2]. Acoustic telemetry is a widely used aquatic tracking method, in which the signals transmitted from implanted or externally attached acoustic transmitters are detected and logged by nearby acoustic receivers. This method can, in theory, enable all tracking equipment across the globe to detect all tags deployed and active at a given time—as long as all equipment manufacturers use compatible coding schemes operating on the same frequencies. There are currently a number of available systems using different frequencies but mostly using the 69 kHz band, as this frequency is supposed to offer the best solution to the universal trade-off between size of the tags and the resulting detection range of their signals [3].

Most manufacturers use one of two encoding methods: pulse position modulation (PPM) or binary phase shift keying (BFSK). For PPM, the tags transmit a series

of pulses, each encoding their unique ID. The uniqueness of the ID is encoded in the time intervals between the successive pulses. In BFSK, the ID is provided by a single transmitted pulse transmitted as a phase shift on the frequency carrier signal. The phase shift converts to bits (1 and 0), which in turn translates to an ID code. As a result, there are clear trade-offs between each engineering approach that make one more or less useful depending on the applications. Transmission time, power consumption, code collision, frequency use and information transfer clearly differ between PPM and BFSK and technology choice will depend on the environment, species and objectives at stake.

This manuscript will focus on the PPM transmission technology, which is currently by far the most dominant technology, and the emerging problems related to its lack of compatibility.

The rapid worldwide increased use of acoustic telemetry systems in the recent decade soon resulted in high demand for unique identification codes outpacing supply. This led to the problematic phenomenon of duplicate codes, where two different aquatic animals transmit identical IDs within an area, potentially

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confusing interpretations and jeopardizing scientific studies. Duplicate codes are particularly problematic for tags with long battery life used for long-lived and highly migratory marine species. PPM ID number limitations are typically solved by creating different parallel protocols. These protocols differ from one another in their protocol identifier, which is the time between the first two pulses, and in their cyclic redundancy check (CRC). CRC is an error-detecting code used to detect accidental changes to raw data. Manufacturers developed different protocols, and receivers are able to listen to several protocols simultaneously. However, not all protocols are compatible between manufacturers, which poses a serious challenge for research.

Acoustic telemetry is commonly applied to investigate the spatial ecology and behaviour of aquatic species in relation to their environment. It provides a scientific basis for management and conservation and significantly improves our understanding of ecosystem functioning and dynamics [4]. Consequently, there is a clear move towards implementing large-scale, cross-boundary networks [5], such as the Pacific Shelf Ocean Tracking system (POST) [6], the Ocean Tracking Network (OTN) [7], the Florida Atlantic Coast Telemetry working group (FACT) [8], the Great Lakes Acoustic Telemetry Observation System (GLATOS) [9], the Integrated Marine Observing System (IMOS) and the European Tracking Network (ETN). Next to physical infrastructure, these networks have a central data repository, where (meta) data from acoustic telemetry studies are archived, which allows for improved collaboration and data sharing [10, 16, 17]. Researchers aim to deliver state of the art and relevant science utilizing a global network of equipment and scientists that work together to achieve common goals. To optimise the investment and data output, these networks require completely compatible acoustic telemetry systems allowing for flexibility to operate tags and equipment produced by all the equipment manufacturers.

Issues related to PPM protocols

A variety of PPM protocols are used by the manufacturers of acoustic telemetry devices globally (Innovasea, Lotek, Sonotronics, and Thelma-Biotel), some of which have been shared for decades (i.e., R64K, S256, R04K, R256), whereas others are considered proprietary and are, therefore, encrypted. Shared protocols allow for compatibility among brands, facilitating the establishment of a global tracking system. However, care must be taken to avoid unintentional ID duplication. To date, code duplication has been mitigated by an informal agreement among manufacturers for the shared protocols, with a block ID allocation assigned to each brand (pers. comm.). Manufacturers' encrypted protocols avoid ID duplication to

some extent, yet do not prevent false detections on other protocols, because these are not shared. Encryption also stymies compatibility between equipment of different brands (Table 1).

The recent evolution from shared protocols towards encrypted systems hinders the development of globally compatible animal tracking networks and also limits a researcher's ability to "mix and match" telemetry equipment from different manufacturers to best address the objectives in mind. Each manufacturer offers specific tag and receiver solutions that are ideal for certain applications and these equipment choices should not be excluded by locking into a particular brand. In practice, the large initial investment in infrastructure required to set up a tracking network will effectively tie researchers to a single operating system and brand, creating obstacles to future network compatibility, collaborations, and options for future study designs.

From a science perspective, this dependency stifles innovation [11] within the acoustic telemetry community and restricts the scope, type, and flexibility of research [12]. Dominance of one company will also reduce competition among manufacturers, resulting in greater costs for researchers [13] and potential conflicts with legal requirements for competition fairness at national and/or international level [21]. From a corporate perspective, market dominance does not necessarily violate anti-trust legislation. In Europe, for instance, regulators give wide leeway to competing firms with duelling technologies. Although universality would have clear social or economic benefits, free market competition permits different types/technologies/models because of intellectual property rights [14, 15, 22].

In practice, complex combinations of different systems have arisen. In Europe, for example, a variety of systems (from different manufacturers) are in use across environments and geographic regions [4]. Many countries involved in ETN combine equipment from several brands, while neighboring countries might be using incompatible systems (Fig. 1). Similar situations can occur across the globe and will increase in years to come unless this incompatibility problem is tackled. All aquatic animal telemetry data (and associated metadata) collected in Europe can be archived in the ETN database [10]. This recent and rapidly growing data repository [10, 16, 17] hosts ca. 260 users from 80 institutes across Europe at the date of publication. It archives (meta) data from over 260 projects reaching 490 million acoustic telemetry detections. As ETN adopts the FAIR data principles, the relevant (meta)data are shared among the collaborators and made openly available at the earliest convenience. These facts clearly highlight the need to ensure cross-European compatible protocols in acoustic

Table 1 Tag protocols available at the different manufacturers

Old name	Thelma	Sonotronics	Lotek	MAP-110*	MAP-112*	MAP-113*	MAP-114*	MAP-115*
<i>Unique code sets compatible between manufacturers</i>								
	OPI	OPI	OPI					
	OPs	OPs	OPs					
R64K	A69-1303	A69-1303	A69-1303	A69-1303	A69-1303	A69-1303	A69-1303	-
S256	A69-1105	A69-1105	A69-1105	A69-1105	A69-1105	A69-1105	-	-
R04K	A69-1206	A69-1206	-	A69-1206	A69-1206	-	-	-
R256	A69-1008	-	-	A69-1008	-	-	-	-
<i>Unique code sets NON-compatible between manufacturers</i>								
	HS256	ACT	Lotek Map				A69-9007	A69-9007
	DS256					A69-9006	A69-9006	A69-9006
	R01M				A69-9005			
	S64K				A69-9004	A69-9004	A69-9004	A69-9004
					A69-9002	A69-9002	A69-9002	A69-9002
					A69-9001	A69-9001	A69-9001	A69-9001
								A69-1605
						A69-1602	A69-1602	A69-1602
					A69-1601	A69-1601	A69-1601	A69-1601

Protocols of the same colour are compatible. OPI and OPs are new protocols that are available for all manufacturers and supported by the ETN

* Vemco/Innovasea protocol sets

telemetry. Introducing encrypted protocols would prevent this compatibility, compromising collaborations between users and resulting in loss of valuable data at the regional and European level. This will inevitably jeopardize ETN’s primary goal of fostering broad scale collaboration in the marine research community [4]. The same rationale can be applied to other regional networks.

A solution through collaboration

It is now clear that encrypted protocols in acoustic telemetry do not support scientific collaboration and should be avoided by the user community.

Thus, moving forward towards much-needed international collaborative networks, that can provide crucial conservation and management information to decision-makers, objectively require compatibility between brands and agreements on transmission protocols and ID allocation. This may be achieved if researchers and industry work in close collaboration to advance the optimisation and development of biotelemetric technology.

Medium-term solution

As a medium-term solution, two robust and energy-efficient transmission protocols were developed for the aquatic research community: Open Protocol ID (OPI) for ID tags and Open Protocol sensor (OPs) for sensor tags. Both protocols use PPM transmission technology at

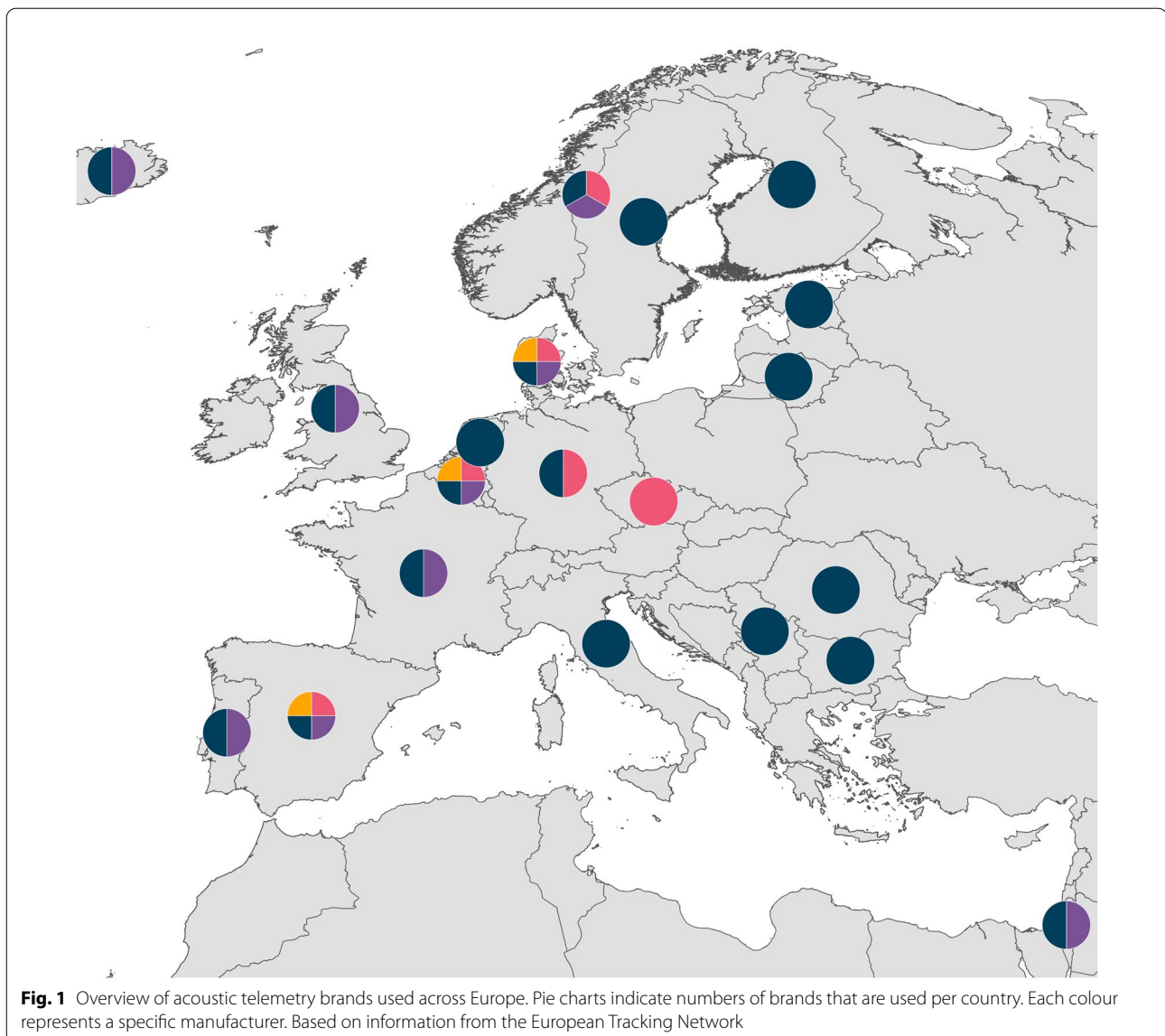
69 kHz. The total duration of a pulse train varies based on the data, but is limited to a maximum of 4.2 s for OPI and 4.8 s for OPs. OPI supports over 1 million unique IDs, while OPs supports over 64,000 unique IDs with up to 4096 data points resolution.

The protocols are available for all interested manufacturers upon agreeing with the terms of participation as stated in a Memorandum of Understanding (MoU) [23]. In its initial current phase, OPI and Ops are support by Lotek, Sonotronics, Star-Oddi and Thelma-Biotel. Opening the infrastructure networks of acoustic telemetry to all manufacturers of different types of sensors and tags will drive innovation, and will boost availability of new solutions for future research. From personal communications with manufacturers that signed the MoU it is clear that they are already working on these developments.

Testing the compatibility

When a new protocol is introduced, several tests need to be performed.

First, compatibility should be tested and validated between the different brands. A pilot compatibility study was performed in lake Hald, Denmark (56.38 N, 9.35 E) from 2020-01-27 to 2020-02-05. Four Thelma-Biotel, one Lotek, and one Sonotronics receivers were deployed at three locations in the lake. A total of eight low power tags were co-deployed on a mooring



south–west of the receivers and eight high power tags were co-deployed on a mooring to the north–east of the receivers. The tags were taped to an 8 mm rope. Each tag operated on the R64k, OPs or OPi coding scheme. The test resulted in all protocols being detected across different receivers, thus confirming full interoperability between different manufacturers. Direct comparison between brands was not performed as different sizes of tags, shape and transmission power were used on each batch.

Second, interference with existing systems needs to be understood to mitigate potential negative effects. This is partly the responsibility of the manufacturers and should be performed in simulation tests in the lab. However, the research community also aims to take

responsibility for carefully testing compatibility and general performance in relation to interference, range and detectability. Currently, several independent tests are being undertaken by scientists across Europe [24] to address these topics. We warmly welcome more scientists to perform these types of tests across different environments across the globe.

Future perspectives

We conclude that technological advances are very much needed. On the engineering side, the PPM coding scheme was not specifically designed to meet the growing demand and has clearly outgrown its use. It is thus time for a complete rethink of the technology and

the development of a completely open-source coding system.

Technological advances will be an important catalyst for the future of aquatic animal tracking [2, 18]. We recognise that our proposed solution towards compatibility is only a medium-term solution. In the longer term, technological advancements in acoustic telemetry equipment that broadly support openness and sharing need to be continued and broadened in scope, both on the software and hardware sides. In particular, these should promote the individual researchers' capacity to have more control on the settings of both receivers and tags and to take deliberate, expertise-based decisions in the setup and design. Equipment of the different brands has different features available, which promotes competition. However, other telemetry and biologging devices such as satellite transmitters and multi-sensor biologging packages allow high user control in setting up duty cycles [19]. This is not yet the case in passive acoustic devices, which are more 'black box' by comparison.

In addition, further agreements on both existing and future protocols should be made. For example, although we focused on protocols utilizing the 69 kHz frequency for the sake of urgency, compatibility on other frequencies should be considered as well.

Up to now, ETN has engaged to strive towards fully compatible acoustic telemetry networks, and has worked to highlight its importance to the research community. This issue has been most urgent in Europe, where researchers have been more cosmopolitan in their choices of telemetry equipment. The issue of compatibility may, therefore, not yet be viewed as a global issue for the other networks, but we urge other users and networks to take up this engagement of equipment interoperability for the sake and future of independent science. In our view, only a truly interconnected and compatible global telemetry network and community will be able to address the many and difficult challenges ahead for the sustainable management and conservation of our rivers, seas and oceans.

Abbreviations

BFSK: Binary phase shift keying; CRC: Cyclic redundancy check; ETN: European tracking network; FACT: Florida Atlantic Coast Telemetry working group; GLATOS: Great Lakes Acoustic Telemetry Observation System; IMOS: Integrated Marine Observing System; OP: Open Protocol; OPi: Open Protocol ID; OPs: Open Protocol sensor; OTN: Ocean tracking network; POST: Pacific Shelf Ocean Tracking system; PPM: Pulse position modulation.

Acknowledgements

This publication is based upon work from COST Action CA18102, supported by COST (European Cooperation in Science and Technology). This work was supported by the Research Foundation Flanders (FWO) as part of the Belgian contribution to LifeWatch.

We thank Robert Lennox and Edward Knapp for their constructive comments and suggestions on earlier versions of the manuscript. We thank the reviewers for their input.

Authors' contributions

All authors were major contributors in writing the manuscript. All authors read and approved the final manuscript.

Funding

This work was supported by the Research Foundation Flanders (FWO) as part of the Belgian contribution to LifeWatch, and the Danish Net and Fish Licence Funds.

Availability of data and materials

Data sharing is not applicable to this article as no data sets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Received: 26 February 2021 Accepted: 6 July 2021

Published online: 26 August 2021

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