# Magenta and alternative red colour spectroscopy on nautical charts in the visible and near-infrared electromagnetic spectrum

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## Abstract

The International Hydrographic Organization (IHO) publishes Regulations and Technical specifications for the official nautical charts in order to standardize the use of colours to all hydrographic offices of IHO Member States. The use of magenta is reserved for highlighting, drawing attention and to distinguish information to elements of a chart of maritime importance and it is necessary to ensure its visibility.

So far, there is no information on the spectrographic composition of colours intended to highlight specific content. For the first time, spectroscopy of magenta and alternative red colour is performed on the charts of hydrographic offices that have officially published colour compositions. Spectroscopy extends beyond the visible area to the near-infrared part of the electromagnetic spectrum.

The article presents the absorption curves of magenta and red colour that contain information on the spectrographic composition of these colours in the visible and near-infrared spectrum. The purpose of the study is to show what proportion of black colour added to magenta or red can give positive response or positive absorption properties in the near-infrared part of the spectrum.

The results are also part of preparatory research aimed at introducing colour twins, a system of hidden graphical elements designed to protect nautical charts from forgery and to expand their information content.

**Keywords:** nautical charts, spectroscopy, magenta-M, red-R, visible spectrum-V (VIS), near-infrared spectrum-Z (NIR)

## 1 Introduction

The International Hydrographic Organization (IHO) publishes Regulations and Technical Specifications for Nautical Charts with the aim to standardize the use of colours for all hydrographic offices of IHO Member States. In section B of "*IHO Regulations for International (INT) Charts and Chart Specifications of the IHO*" [1], Chapters B-140 to B-147 specifically refer to the use of colours and colour reproduction.

In chapter B-140 [1] initially states that all charts should be printed with minimum of four colours: black, magenta, yellow and blue. Additional colours can be used for better representation of specific navigation areas. The use of alternative colours such as red instead of magenta tends to reduce the desired level of standardization.

The use of magenta is defined in Chapter B-142 [1] and it is reserved for drawing attention to chart elements of particular importance (eg. for symbols or distinguishing information). It is very important that all colours are visible under the coloured (usually red) filters used to dim the light on the bridge. In the case of magenta, this requirement is met by adding a certain percentage of black to ensure better visibility.

Article "Spectrometry of standard colours on Croatian nautical charts" (Jeličić T., Žiljak-Gršić J. and Modrić D., 2019) [2] showed that in the Z1 and Z2 regions of the near-infrared part of the spectrum, there are certain differences in the response between standard colours on Croatian nautical charts.

The article contains a special section "Magenta and Black Spectrometry", where the spectrograms of reflection of these two colours are compared. The results obtained for magenta versus black colour showed the values of the response of these colours in the near-infrared spectrum, which is reason for further research of magenta and its alternative colours in this study.

The emphasis of the research is on measuring and comparing the response of magenta and red colour response in the near-infrared spectrum. Colours should also be visible in the NIR area of the spectrum for the purpose of drawing attention to chart elements of particular importance.

The ultimate goal of carrying out all the aforementioned and related preparatory research is the introduction of a system of hidden graphic elements for the protection of charts against counterfeiting, with the expansion of information content in the NIR area.

## 2 Use of magenta and red colour on nautical charts

Magenta and red colour (in some cases purple) are used exclusively as a colour for distinguishing information or for drawing attention.

The Chart Standardization & Paper Chart Working Group (CSPCWG) asked the offices to submit their CMYK values including colour compositions for magenta and red colour. Some hydrographic offices have kindly allowed their colour codes to be published on the CSPCWG section of the IHO website (Table 1.) [3].

Most hydrographic offices [3] have pure magenta composition (0C 100M 0Y 0K). There are differences in use between countries such as Denmark and Netherland, which use pure red (0C 100M 100Y 0K) for the same purpose. The use in Finland and Norway is very similar except of a smaller percentage of M and Y.

An exception is the example of the Republic of South Africa, whose charts show a combination of 50C 80M 0Y 0K, which gives the colour a distinctly purple tone. For comparison, magenta application on Croatian charts with a low black content (0C 100M 0Y 5K) was included in the research.

**Table 1. Colour compositions for magenta and red colour [3]**

| State | Colour | C% | M% | Y% | K% |
|---|---|---|---|---|---|
| 1. Germany | magenta | 0 | 100 | 0 | 0 |
| 2. Denmark | red | 0 | 100 | 100 | 0 |
| 3. Finland | (light) red | 0 | 90 | 65 | 0 |
| 4. Netherland | red | 0 | 100 | 100 | 0 |
| 5. Norway | (light) red | 0 | 90 | 86 | 0 |
| 6. South Africa | violet, purple | 50 | 80 | 0 | 0 |
| 7. Spain | magenta | 0 | 100 | 0 | 0 |
| 8. Croatia | magenta | 0 | 100 | 0 | 5 |

### 2.1 Specifications of Magenta (B-142 Magenta) [1]

The specifications determine which individual features are displayed on chart with magenta. The general principles for using magenta are that it is reserved for drawing attention to certain characteristics or distinguishing information, such as:

- drawing attention to specific features that have a meaning that extends beyond their immediate location including symbols for: pilot stations, light flares for drawing attention to lights, positions of tidal stream/ current observations, and radio and radar stations - large circles and abbreviations (B-142.1),
- distinguishing information superimposed on the physical features (B-142.2) includes symbols, associated legends, abbreviations, and cautionary notes which indicate transitory physical hazards (eg. ferry routes, submarine exercise areas and transit lanes, firing danger and other military practice areas, sea ice limits etc.),
- features representing a restriction on seabed operations, including anchoring (eg. submarine cables, pipelines, explosive landfill, prohibited anchoring or fishing areas),
- features that represent control or regulation of vessel movement (restricted and prohibited areas, safety zones, routing features such as traffic separation schemes, designated anchorages and berths and other areas such as seaplane landing areas),
- maritime boundaries of legal authority (fisheries limits, territorial waters borders, Harbour and dockyard port limits, customs boundaries in "free ports" etc.),
- certain marginal or other information to be distinguished or emphasized (compass roses, isogonal lines or isogonals, references to other charts and theirs and limits, INT chart number, "DEPTHS IN METRES", "WGS 84 DATUM", and possibly other marginal notes requiring emphasis, symbols and tables for small craft etc.).

### 2.2 Additional use of Magenta (B-142.3) [1]

Magenta colour must be used for specific symbols including: Traffic separation zones; Archipelagic sea lanes; Radar ranges and, when useful, for emphasizing restricted areas. Magenta colour may also be used to subdue submarine cables and pipelines where they may obscure more important black or magenta detail.

## 3 Magenta and red colour spectroscopy on nautical charts

The purpose of this research is to show which percentage of black colour added to magenta or red can cause positive absorption properties in the near-infrared part of the spectrum, because they are of particular importance for application on nautical charts.

It is necessary to ensure the visibility of these colours in both, visible and in the near-infrared region of the spectrum, as well as in the conditions of dim light.

The minimum lighting conditions in the navigation cabin are prescribed by the Croatian Register of Shipping (HRB). The lighting in each room must not be less than the specified values. Specifically, in the navigation cabin, the minimum lighting must not be less than 150 lux.

Figure 1 shows a characteristic port plan with examples from the middle and in the upper right corner. The letter "A" indicates that the Plan is part of a specific chart. For example, on the chart „100-20 Dugi otok - Zadar" there are two plans: Plan A (Port of Gaženica) and Plan B (Port of Zadar).

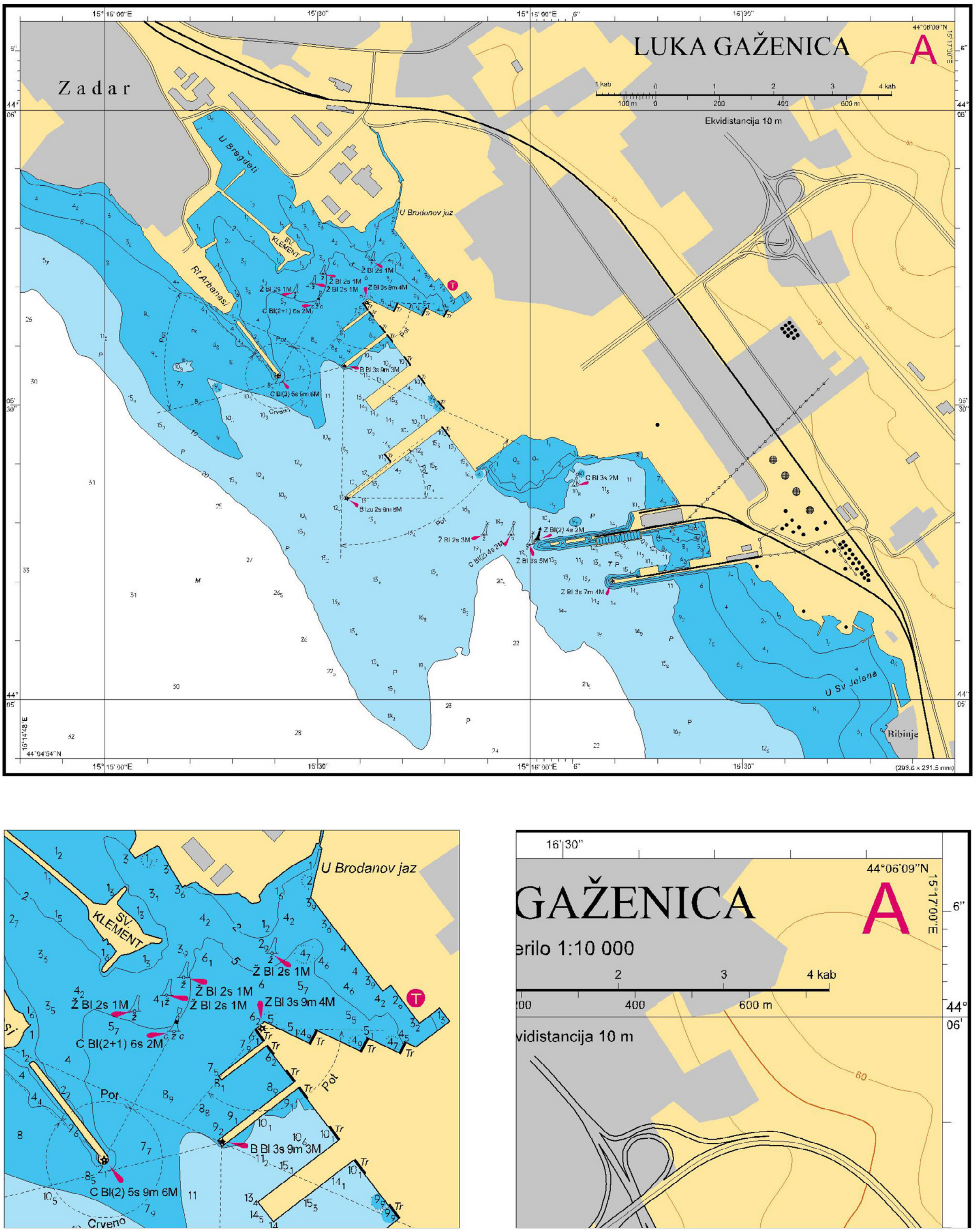


**Figure 1** An example of the use of magenta on the plan „Port of Gaženica"


**Figure 2** An example of response in the visible and near-infrared part of the spectra for three different magenta and red colour compositions

### 3.1 Materials and methods

The printing substrates for the test specimens are:

1. Mondi - Color Copy paper, 100 g / m$^2$, white;
2. Fabriano - Geographical Map paper, 150 g / m$^2$, slightly toned paper.

Printing substrate for charts are cartographic papers that are classified as high-quality papers. Cartographic paper must meet the applicable requirements on board as special working environment conditions (at command bridge), meteorological and oceanological conditions such as wind, seawater, fog, etc.

Particularly important is the resistance to temperature changes and humidity, as well as the resistance to bending, due to which the paper contains a certain proportion of textile fibers. In addition, for the purpose of drawing a navigation routes and various corrections (to keep the chart up-to-date), the paper must be capable of writing and erasing as well as maintaining colour fastness.

Furthermore, to reduce the reflection of light from white paper when using artificial lighting, white paper is not recommended. The usual colour of chart paper is slightly toned paper such as „š*amoa*". The word "šamoa" in Croatian comes from the French language (*fr. chamois*) which originally means processed chamois, goat or sheep skin, and today it is used for a light yellow-brown colour. A very similar colour is also „*beige*", which is used for yellow-brown or gray-brown colour. It is originally from French too (*fr. beige*) and denotes natural wool that has not faded or been dyed. Historically, both colours have their origins in early attempts to drow maps on skin and similar natural materials.

Considering the use of toned paper, for measurement accuracy, it is also necessary to perform spectroscopic measurement of the printing substrate. Therefore, Figure 3 gives the absorption spectrogram of the cartographic paper currently used for Croatian charts.

Due to the impossibility of comparison with previously used toned papers for which there are no spectrographic data, until the agreement of the technical specification of the paper, which will include the exact definition of the paper colour, this article will show the colour spectrography on white paper. Thus, the spectrograms in Figures 4 to 7 show the results for the white background, in order to align the criteria with the previous studies.

The test samples were obtained on a „Xerox Color 560" laser printer using Xerox® EA toner with Ultra Low Melt technology. The printer uses 4 standard CMYK toner cartridges from the Xerox commercial range, with default colour management settings (link: https://www.xerox.com/digital-printing/latest/X56BR-01U.pdf).

The Projectina Docucenter forensic instrument was used for the measurement (link: http://www.telectronics.biz/assets/mainmenu/104/editor/PDF_leaflet_Docucenter_4500.pdf).

The device is used for the purpose of checking documents and valuable papers (securities). In the field of research, it is used for professional and scientific purposes so that claims can be proved by measuring physical values in a reliable manner.

The absorption spectra were measured in the visible range (V) from 400 to 700 nm and extended to the near-infrared part of the spectra Z1 (700 to 800 nm) and Z2 (from 800 to 1000 nm).

### 3.2 Measurements and Results

The first test sample for spectrographic measurement contains eight samples. In addition to the colour samples of the seven offices that have published the colour compositions they apply [3], and a colour sample from the Croatian chart has been added.

The second test sample contains a test wedge with values from 10 to 50% black K, in 10%

increments, to monitor differences between the spectrograms with increasing black content.

The other two test samples consist of pure magenta (100M) and pure red (100M and 100Y), with the addition of 10% black.

These two wedges are intended for interpretation of the results according to the obtained curves on spectrograms with values applied on international charts.

The absorption spectrograms on Figure 3 show a comparison of two substrates (white paper and „*šamoa*" cartographic paper) with an example of magenta absorption with a small fraction of black (Croatian chart).

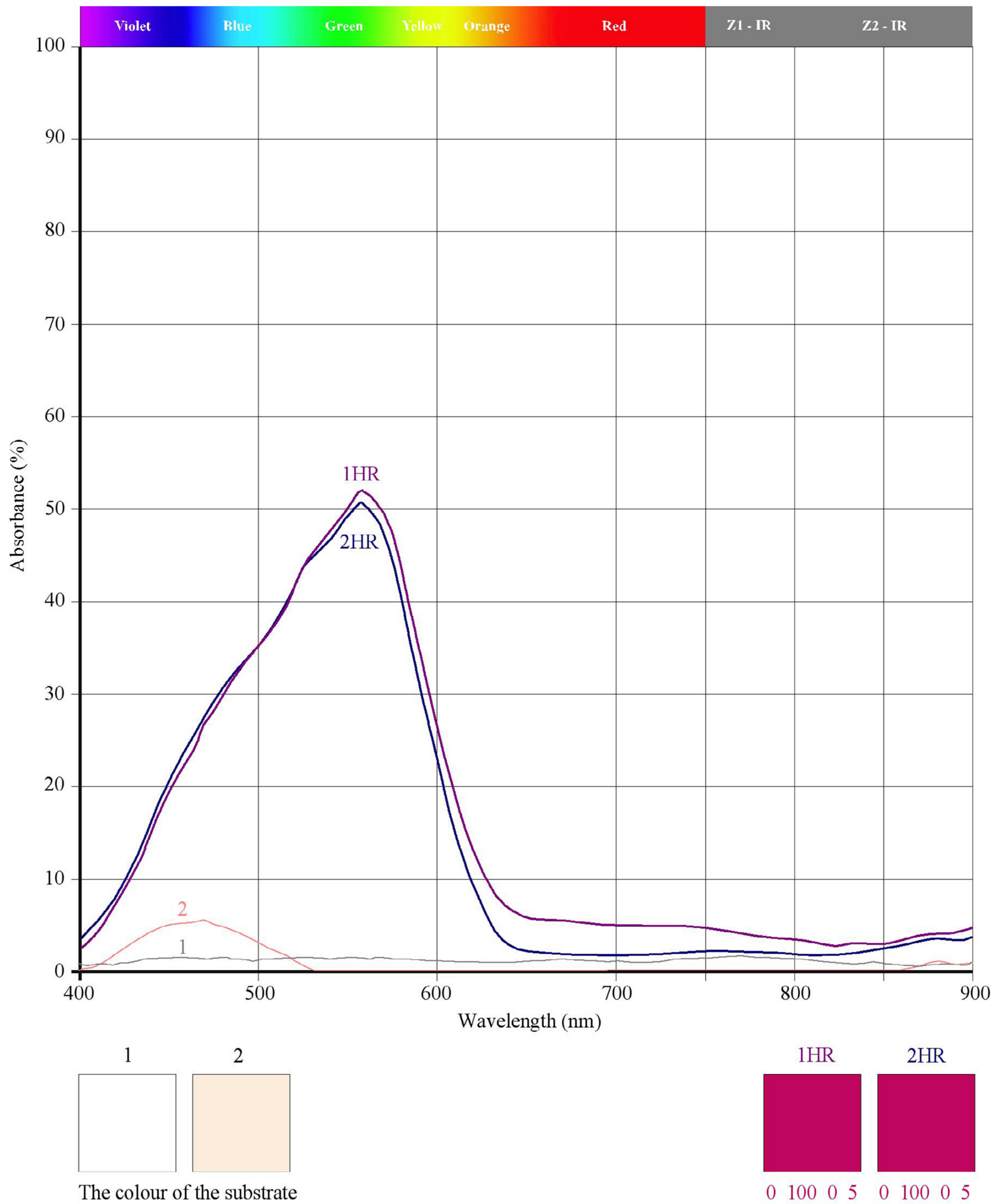


**Figure 3** Absorption spectrograms for different print substrates with an example of magenta absorption

According to the results obtained for the colours of substrates 1 and 2, it is concluded that, except for a small difference in the violet-blue part of the spectrum (about 450 nm), there are no significant deviations between the measured substrates in the other parts of the spectrum.
The slightly increased absorption in the violet-blue part of the spectrum for substrate 2, characteristic for the yellow shades of colour, gives the substrate a certain yellow-brown tone.

The results obtained for pure magenta with 5% K show small differences in the yellow-orange and red parts of the spectrum (<5%), as well as in the near-infrared region, where the response in both cases is extremely low.

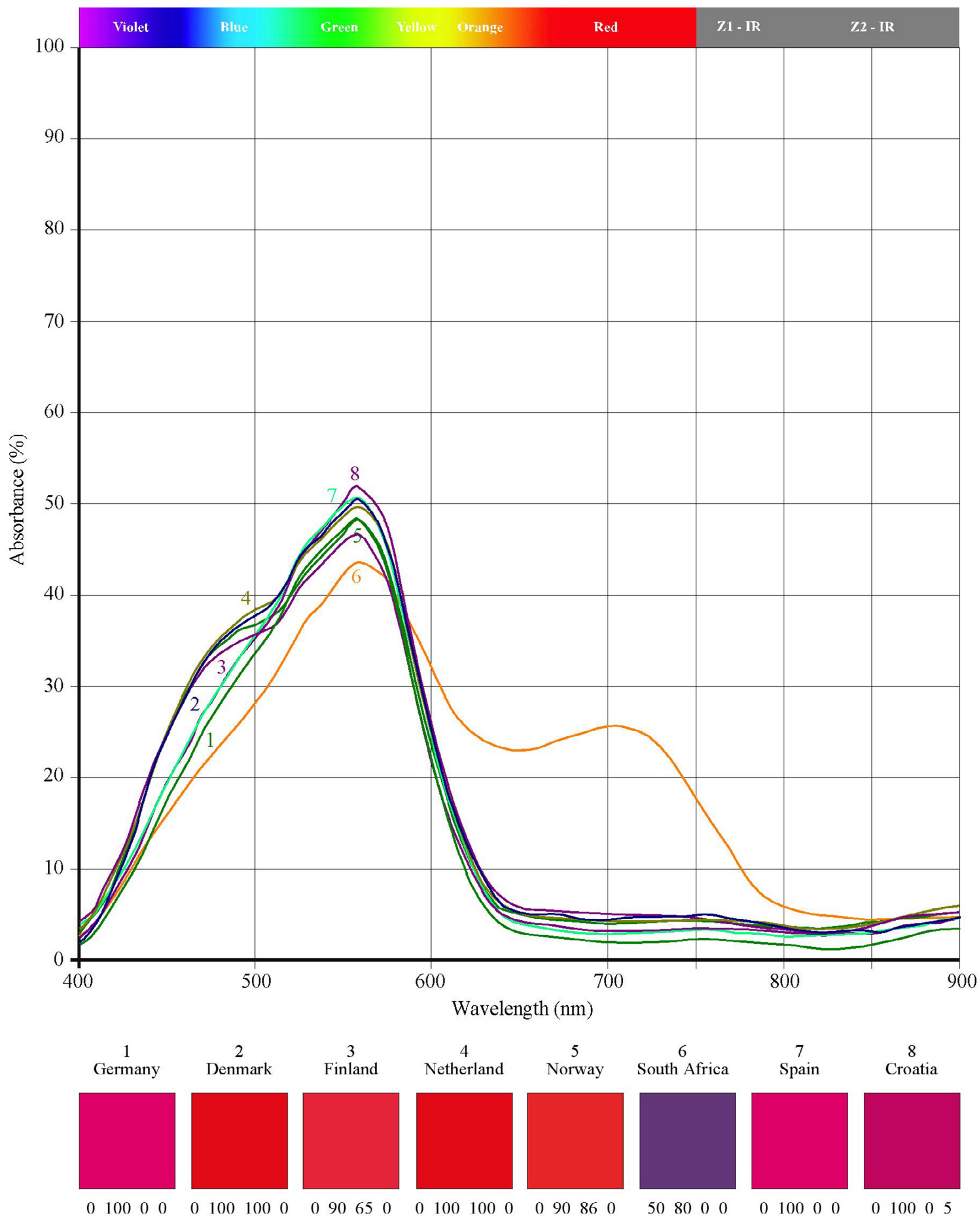


**Figure 4** Absorption spectrograms for the visible and near infrared spectra

For most of the colour samples in Figure 4, the highest absorption values are in the range of about 550 nm, which is expected for the pure colour curves M and R (M+Y). The highest values were measured for samples 1, 7, and 8 for colours composed solely of M. For samples 2, 3, 4, and 5, for colours that have a certain percentage Y in addition to M, a slightly increased absorption was observed on the spectrogram in area of about 450 nm, which is a characteristic of R.

This means less reflection in the violet-blue part of the spectrum and a shift from magenta to red.

The exception is sample 6 with a distinctly purple (violet) tone, and in addition to the

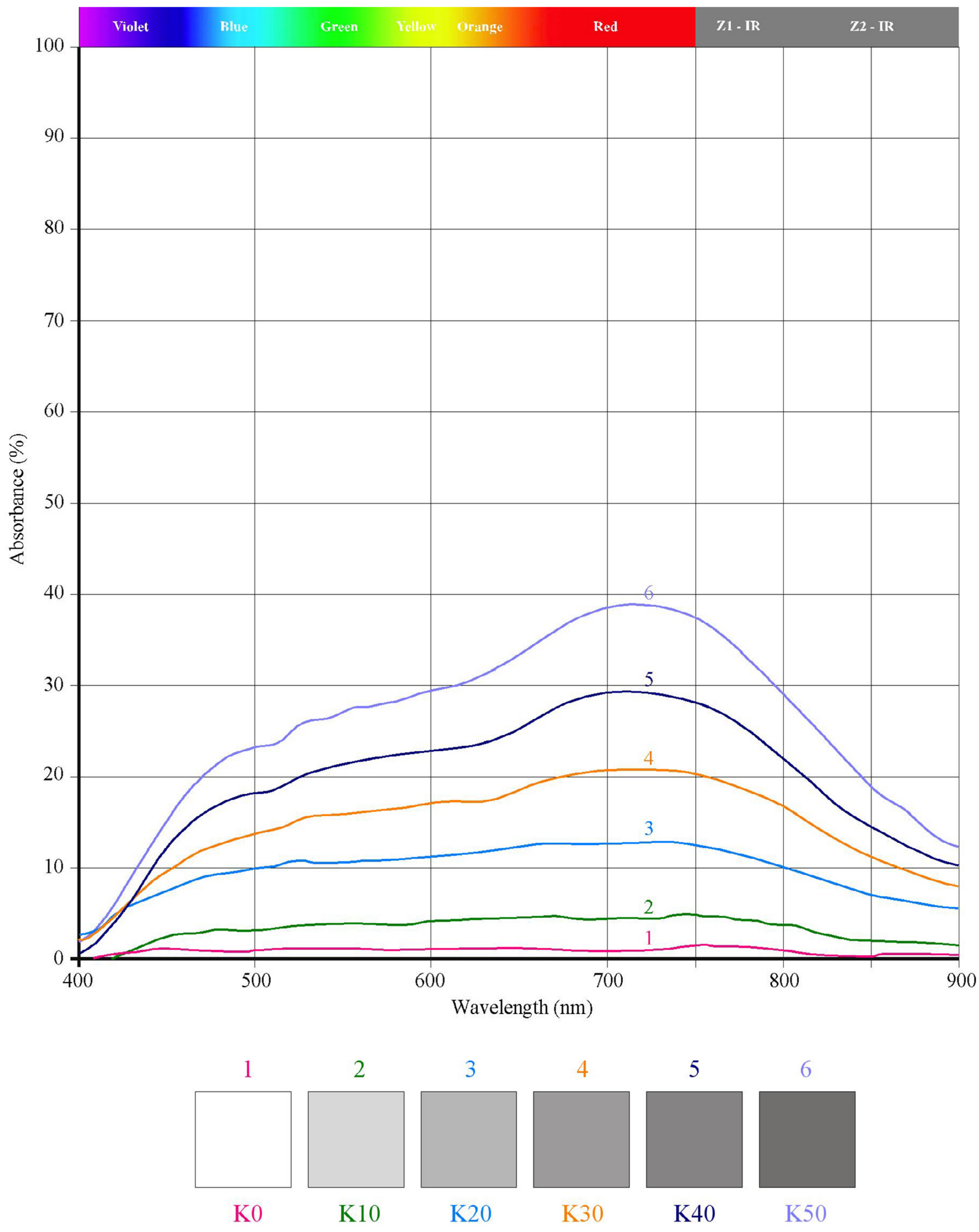


**Figure 5** Absorption spectrograms for visible and near-infrared spectra for black colour

absorption peak at 550 nm, the so-called „*knee*" at 700 nm, precisely because of the high cyan (C) content of the purple.

The comparison of the measurment results for black from 10 to 50% proportions is shown in Figure 5. Despite the highest absorption values in the range of 700 to 750 nm, gray achromatic colour tone is dominant for uniform absorption across the spectrum.

A larger difference in absorption is observed in the Z1 region. This is especially visible for curves 3 to 6, which are in the observed range with respect to curves 1 and 2 of significantly higher values, whereas in the Z2 region this difference decreases.

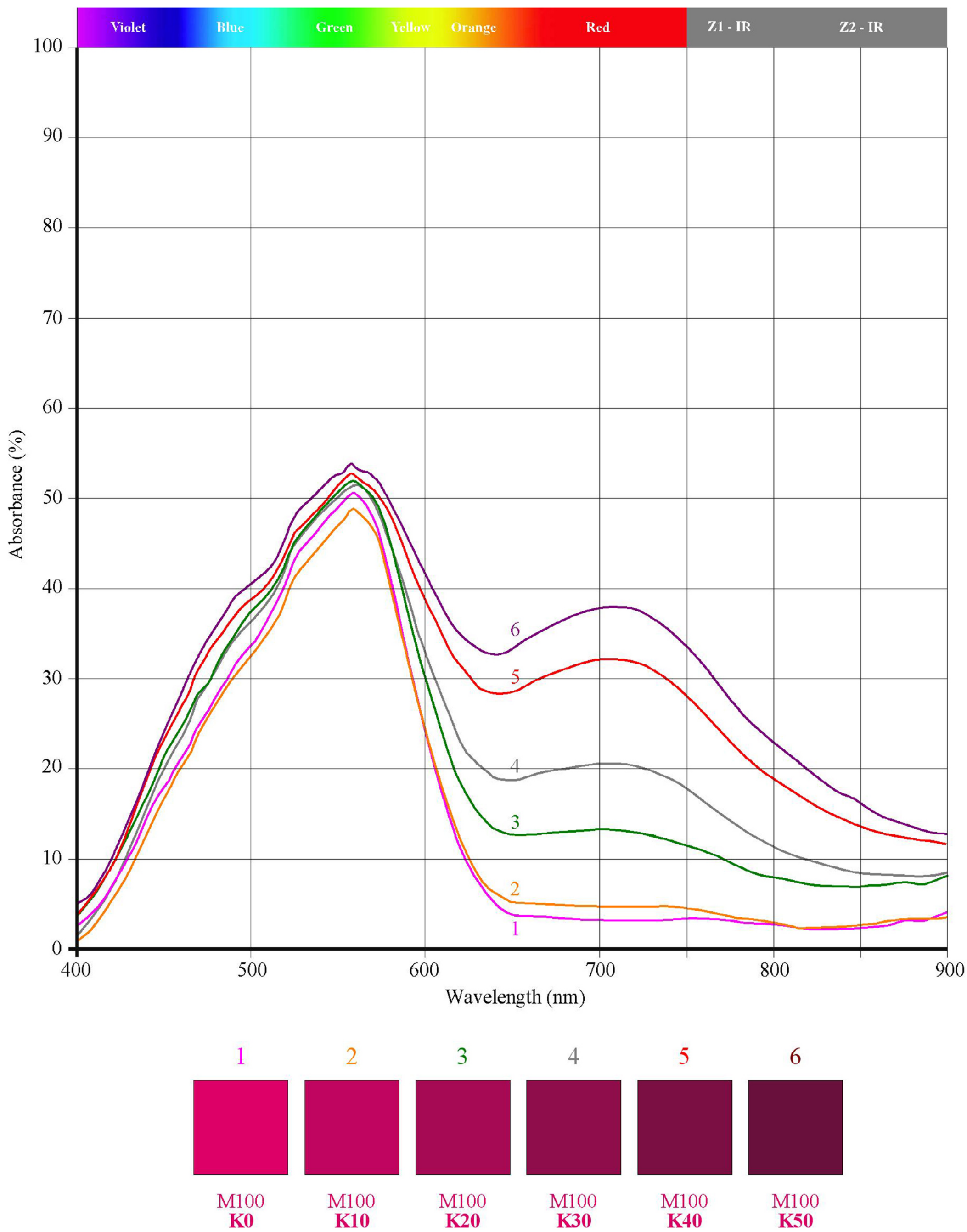


**Figure 6** **Absorption spectrograms for the visible and near-infrared spectra for 100% M with the addition of 10 to 50% K colour**

According to the article "Near-infrared spectroscopy in print technology" (Žiljak-Gršić J., 2017) [4] at 900 nm, we observe the values of ΔZ, which for the K values of 40 and 50% are above 0.10. Introduced value ΔZ is the difference in the absorption of light of V and Z dyes in the visible and near-infrared part of the spectrum. The value ΔE is a measure of the difference or equality of the two colours in the V region, while the measure of ΔZ refers only to the Z region.

The spectrograms in Figure 6 clearly show similar values in the 550 nm range for all measured colours. Differences occur in the region above 600 nm due to the increase in

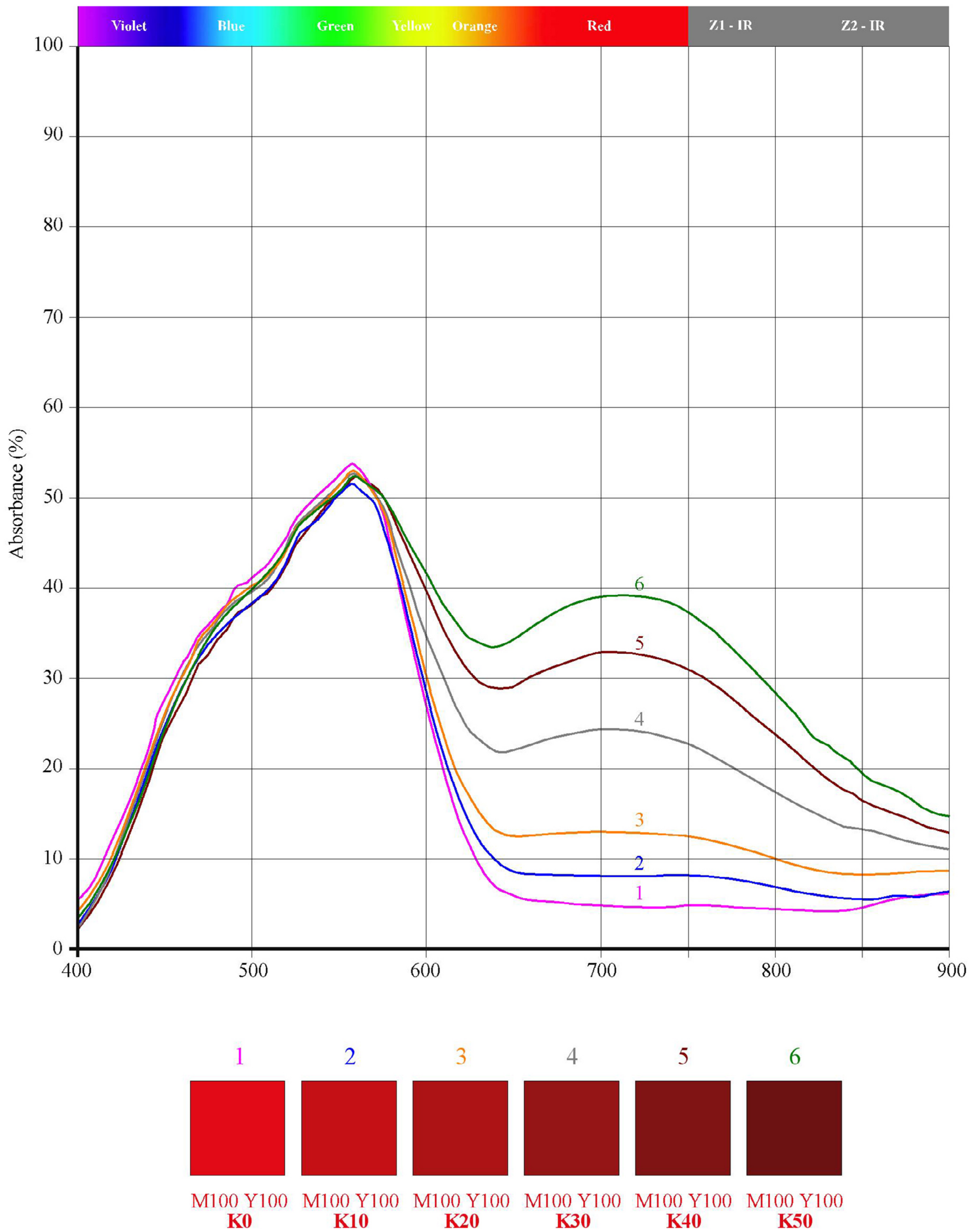


**Figure 7** **Absorption spectrograms for the visible and near-infrared spectra for R (100% M + 100% Y) with the addition of 10 to 50% K**

absorption in the red region of the spectrum created by the addition of black.

Although a reduced absorption was noticeable in the 800 to 900 nm range, the ΔZ values remained above 0.10, and adding 40% or 50% black content in magenta was chosen to achieve the desired response in the Z2 region.

The spectrograms in Figure 7 as in the previous example show similar absorption peaks in the 550 nm range for all dyes measured. Differences also occur in the region above 600 nm for reduced reflectance in the red region of the spectrum (darker colours) which, by adding a proportion of black, tend to be more dark, brownish-red colour (maroon, burgundy).

Although an reduced absorption was noticeable in the 800 to 900 nm range, the values of ΔZ were maintained above 0.10 for samples 4, 5, and 6. Therefore, the choice of 30 to 50% black added in red is appropriate to achieve the desired positive response in the Z2 area.

The use of higher proportions of black than 50% in the observed colours is not recommended in order to maintain a noticeable difference between these colours and the black colour, which is also contained in the IHO recommendations.

Therefore, the optimum value of the proportion of black in magenta and red is 30-40% which gives values of ΔZ > 0.10.

Earlier research has proven that the black content of 40% meets the separation requirements and remains constant for the readability of the Z image. Changing the proportion of black is possible and setting any reasonable value for this purpose is permitted. However, 40% black ratio is often the reference (optimal) combination value between Kmin and Kmax, according to the "Appliance of achromatic arrangement for visual and Z images at NIR technology " (Agić D., Agić A., Stanić-Loknar N., 2019.) [5].

## 4 Discussion

The results of spectroscopy shown on the spectral curves are based on measuring the values of the actual colour coverage obtained by printing on a specific laser printer and printing substrate. A dot-gain that would provide additional indicators is not specifically considered for this study but is recommended for future research.

According to the results of spectroscopy, it is evident that magenta and red achieve positive light absorption properties in the near-infrared by adding proportions of black.

According to Fig. 6 the proportions of black of 40 and 50% showed increased absorption in the Z2 region. Absorption values above 10% in Fig. 7 are measured according to spectrograms for the proportions of 40 and 50% black, while Fig. 8 shows values above 10% absorption for the proportions of 30 to 50% black.

## 5 Conclusion

The absorption spectra of magenta and red, colours that are of particular importance for nautical charts, show that at a black ratio of 30-40%, regardless of the application of magenta or red, the positive absorption properties are shown. The visibility of these colours in the visible as well as in the near-infrared spectrum is extremely important in dim light conditions as well as in the near-infrared region.

Since the intention of the research is to introduce security elements in the near-infrared part of the spectrum, it is necessary to ensure the visibility of other important colours, for example for the basic chart elements as well as highlight colours, such as black and magenta or red.

In this regard, it is concluded that for use on nautical charts, irrespective of the application of magenta or red, the addition of black in the proportion of 30-40% is recommended in order to make the chart elements visible at wavelengths above 700 to 1000 nm.

It is important to emphasize that the colour combinations of security elements must be adapted to all different substrates or printing techniques to achieve the same output colour values.

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