Investigation of a Beta Spectrum through Virtual MCA Supported By Virtual Oscilloscope

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Graphical/Tabular Abstract (Grafik Özet)

The study aimed to test the performance of a developed virtual MCA (Multichannel Analyzer) in a beta spectrometer. Besides, an oscilloscope feature was brought in to the virtual MCA different from the conventional ones. The results obtained from virtual instruments were compared with those of the real ones. / Bu çalışma, geliştirilen sanal MCA'nın (Çok Kanallı Analizör) performansını bir beta spektrometresinde test etmeyi amaçlamıştır. Ayrıca, gerçek cihazlardan farklı olarak sanal MCA'ya bir osiloskop özelliği getirilmiştir. Sanal cihazlardan elde edilen sonuçlar gerçek cihazlardan elde edilenlerle karşılaştırılmıştır.
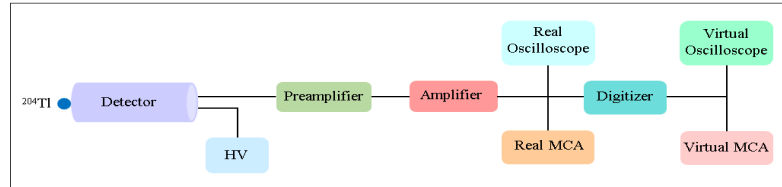
Figure A: Circuit schema used in the experiment (HV: high voltage power supply)

/**Şekil A:** Deneyde kullanılan devre şeması(HV: yüksek voltaj güç kaynağı)

Highlights (Önemli noktalar)

➢ Developed virtual MCA was used to accumulate the beta energy spectrum. / Geliştirilen sanal MCA beta enerji spektrumunu elde etmek için kullanılmıştır.

➢ Virtual oscilloscope was utilized for displaying the signals in beta spectrometer. / Sanal osiloskop beta spektrometresinde sinyalleri görüntülemek için kullanılmıştır.

➢ The performances of the developed virtual MCA and virtual oscilloscope were tested by comparing them with the real ones. / Geliştirilen sanal MCA ve sanal osiloskobun performansı gerçekleriyle karşılaştırılarak test edilmiştir.

Aim (Amaç): *It was aimed to obtain the beta spectrum via the virtual MCA and to display the output signals of a main amplifier in the virtual oscilloscope. / Sanal MCA vasıtasıyla beta spektrumlarının elde edilmesi ve ana yükselticinin çıkış sinyallerinin sanal osiloskopta görüntülenmesi amaçlanmıştır.*

Originality (Özgünlük): *A virtual MCA supported by a virtual oscilloscope was developed by writing a code via LabVIEW software functions, and it was used in a beta spectrometer. / LabVIEW yazılım fonksiyonları aracılığıyla kod yazılarak sanal bir osiloskop ile desteklenen bir sanal MCA geliştirilmiştir ve beta spektrometresinde kullanılmıştır.*

Results (Bulgular): *It was seen that the results from the virtual MCA and virtual oscilloscope were highly compatible with those of the real ones. / Sanal MCA ve sanal osiloskoptan elde edilen sonuçların gerçeklerinden elde edilen sonuçlarla oldukça uyumlu olduğu görülmüştür.*

Conclusion (Sonuç): *It was deduced that the developed virtual MCA and the virtual oscilloscope could be operated in nuclear physics experiments as an alternative option to the real ones. / Geliştirilen sanal MCA ve sanal osiloskobun nükleer fizik deneylerinde gerçeklerine alternatif olarak çalıştırılabileceği sonucuna varılmıştır.*

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Abstract

In this study, the performance of a developed virtual MCA (Multichannel Analyzer) was tested in a beta spectrometer. A real MCA was also used in the spectrometer to compare the results from the virtual one. The beta energy spectrum of a [204]Tl radioactive source was displayed in the real and virtual MCAs. Total counts in the spectra from both MCAs were determined for different data acquisition times. In addition to the total counts, spectrum shapes, starting and ending channel numbers of the beta spectrum from the virtual MCA were also compared with those of the real one. Besides, an oscilloscope feature was brought in to the virtual MCA different from the conventional ones. The output signal shapes of a main amplifier through the detector were displayed in a real oscilloscope and the developed virtual oscilloscope to test this feature. It was noticed that results from both MCAs and oscilloscopes were highly compatible with each other. It is concluded that the developed virtual MCA supported by the virtual oscilloscope could be used like a real one.

Sanal Osiloskop İle Desteklenen Sanal MCA Vasıtasıyla Bir Beta Spektrumunun İncelenmesi

Öz

Bu çalışmada, geliştirilen bir sanal MCA'nın (Çok Kanallı Analizör) performansı bir beta spektrometresinde test edilmiştir. Sanal MCA'dan elde edilen sonuçları karşılaştırmak için spektrometrede gerçek bir MCA da kullanılmıştır. [204]Tl radyoaktif kaynağının beta enerji spektrumu gerçek ve sanal MCA'da görüntülenmiştir. Her iki MCA'dan farklı veri toplama süreleri için spektrumlardaki toplam sayımlar belirlenmiştir. Toplam sayımların yanı sıra, sanal MCA'dan elde edilen spektrum şekilleri, beta spektrumunun başlangıç ve bitiş kanal numaraları gerçek MCA'dan elde edilenlerle de karşılaştırılmıştır. Ayrıca, sanal MCA'ya geleneksel olanlardan farklı olarak bir osiloskop özelliği eklenmiştir. Bu özelliği test etmek için bir ana yükselticinin çıkış sinyal şekilleri gerçek bir osiloskopta ve geliştirilen sanal osiloskopta görüntülenmiştir. Hem MCA'lardan hem de osiloskoplardan elde edilen sonuçların birbirleriyle oldukça uyumlu olduğu gözlenmiştir. Sanal osiloskop destekli olarak geliştirilen sanal MCA'nın gerçeği gibi kullanılabileceği sonucuna varılmıştır.

1. INTRODUCTION (GİRİŞ)

Measuring the height of each of the pulses and counting the numbers occurring within small voltage ranges are the task for a MCA (Multichannel Analyzer). The resulting list of numbers of counts is spectrum of radiation source because the height of each pulse is proportional to the amount of energy absorbed in the detector [1]. A MCA device produced by a company was called here as the real MCA. Its screen is shown in Figure 1 as an illustration.
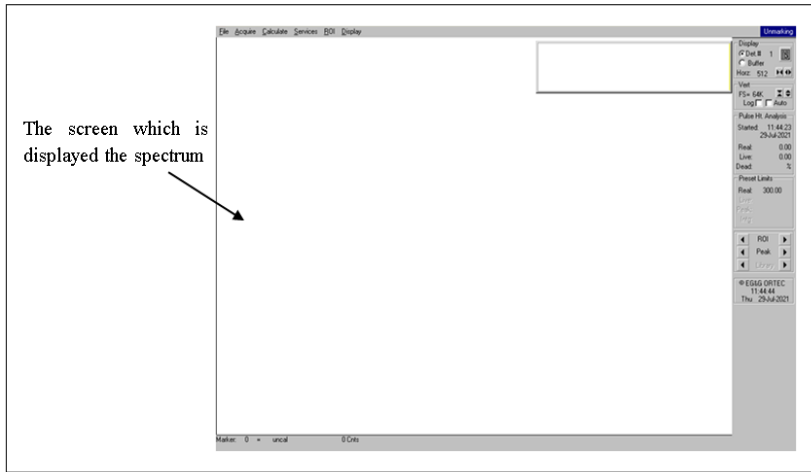
Figure 1. Screen of the real MCA (Gerçek MCA'nın ekranı)

Software applications are developed by programmers in order to increase efficiency and productivity in various situations. LabVIEW (Laboratory Virtual Instrument Engineering Workbench) is a powerful tool that can be used to help achieve these goals [2]. One of the most powerful features that LabVIEW offers engineers and scientists is graphical programming. By using LabVIEW software, the user can design custom virtual instruments by creating a graphical user interface on the computer screen through which one can control selected hardware, analyze acquired data and display results [3].

Virtual MCA is an instrument which can be developed by using LabVIEW software functions. It can be used to display the energy spectrum of a radiation source. It is also possible to add the additional features to the virtual MCA since it is designed by writing the code via the software. In the front panel of the virtual MCA, a screen and an indicator are used to display the spectrum and to show the total counts in the spectrum, respectively.

Oscilloscope is a device used to display the incoming signals from a function generator or a radiation detector. The photograph of the real oscilloscope that utilized here is given in Figure 2 as an illustration.

Figure 2. Photograph of the used real oscilloscope [4] (Kullanılan gerçek osiloskobun fotoğrafı[4])

Virtual oscilloscope is an instrument developed via software in a computer environment. It can be used to display the signals produced by the radiation detectors in nuclear spectrometers.

Spectroscopy is the aspect of radiation measurements that deals with measuring the energy distribution of particles which are emitted by a radioactive source or produced by a nuclear reaction. A particle energy spectrum is a function that gives the distribution of particles in terms of their energies [5].

A variety of information on detected radiation in the form of electrical signals is provided by detectors. However, the signal must be further processed by an electronic system in order to extract this information [6].

In the literature, Amri et al. presented a new open-source software package for analysis of gamma-ray spectra. The software was created by using Java programming language with the JFreeChart library [7]. A flexible and low-cost digital multichannel analyzer based on FPGA (field-programmable gate array) was developed by Cao, Dinh, Nguyen et al. [8]. Tektas and Celiktas introduced a virtual MCA code for use it in a gamma spectrometer [9]. For Mössbauer spectroscopy, an open source MCA was designed by Giraldo et al. Digilent Chipkit uC32 device compatible with Arduino was used to program the MCA by the authors [10]. Gamma-ray energy spectra were obtained through analogue and digital methods by Ermiş et al. [11].

In the present study, a virtual MCA was developed via LabVIEW software functions in a computer environment. In order to obtain beta energy spectrum, the performance of the virtual MCA was tested, and its spectrum results were compared with those of the real MCA. In addition, the performance of the developed virtual oscilloscope inserted in the virtual MCA was tested in the used beta spectrometer.

2. MATERIALS AND METHODS (MATERYAL VE METOD)

The virtual MCA was developed through the software. All processes in the developed virtual MCA, such as determining the amplitude values of the incoming signals, displaying the spectrum, were performed by the software functions. Data were acquired through the driver function (NI-SCOPE) of the used digitizer. Acquired data were sent to "Peak Detector.vi" function which was used to determine the amplitude values of the signals without the use of a special filtering function. For displaying the spectrum, these values were processed by "General Histogram.vi" function.

In this study, we aimed to acquire the beta energy spectrum in the developed virtual MCA. For this, a solid point ^{204}Tl radioactive source (0.25 µCi) which emits beta radiation was used in the experiment. The particles emitted from the source were detected by a BC-400 type plastic scintillation detector (REXON), and the signals from the detector were transmitted to a preamplifier (ORTEC 113) and an amplifier (ORTEC 485), respectively. The preamplifier is an interface between the detector and the following pulse-processing and analyzing electronics. Pulse shaping and amplitude gain are provided by a linear or main amplifier element in the pulse-processing chain [12]. To proceed the detector signals with the virtual oscilloscope and the virtual MCA, analog signals from the amplifier must be digitized. Therefore, a digitizer (NI USB-5133) was used in the experiment. It has sample rate of 100 MS/s and the 8-bit resolution [13]. The signals from the amplifier can directly be sent to a real oscilloscope (GW Instek GDS-2204) and a real MCA (ORTEC TRUMP 8k) because of the fact that they have own ADCs (Analog-to-Digital Converter). For obtaining the beta spectrum, the output signals of the amplifier were sent directly to the real and virtual MCAs through the digitizer. To display the signal shapes in the virtual and real oscilloscopes, similarly, the devices were fed in the same way. Used block diagram in this study is illustrated in Figure 3.
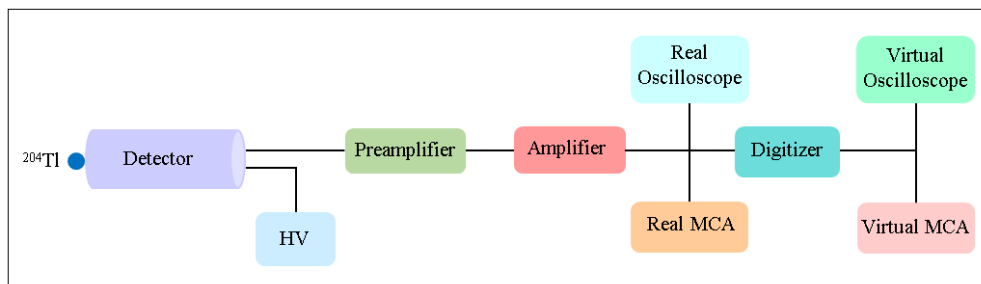

Figure 3. Circuit schema used in the experiment (HV: high voltage power supply) (Deneyde kullanılan devre şeması(HV: yüksek voltaj güç kaynağı))

In the experiment, source-to-detector distance was kept as close as possible to the detector surface to detect more particles from the radiation source. The beta spectra were displayed on the screens of both MCAs for the coarse and fine gain values of 32 and 3 of the used amplifier, which they are the optimal settings for the spectra, respectively. These gain values were kept unchanged during the measurements. The spectra were displayed in the real and virtual MCAs for the data acquisition times of 100, 200 and 300 s. The total counts in the spectra were identified from both MCAs, and the spectrum

shapes were compared with each other. In addition to these, the starting and ending channel numbers (ch. no.) of the energy spectra from both MCAs were determined. Starting channel is the channel number acquired first count in the spectrum, and ending channel is the channel number with first zero count following the starting channel number. An illustration that shows the starting and ending channel numbers is given in Figure 4. In the figure, red (cursor 0) and yellow (cursor 1) cursors show the starting and ending channel numbers, respectively. These channel numbers are set by user through the cursors.
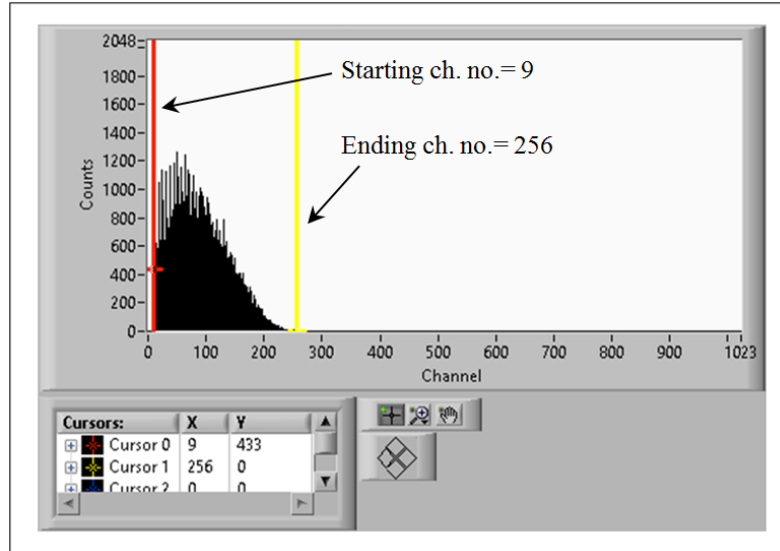

Figure 4. Illustration for starting and ending channel numbers (Başlangıç ve bitiş kanal numaralarını gösteren görsel)

Obtained experimental results are given in the next section.

3. RESULTS (BULGULAR)

The beta spectrum was displayed on the real and virtual MCA screens for the data acquisition times of 100, 200 and 300 s. As a performance test, the total counts in the spectra were obtained from both MCAs, and these results are given in Table 1. The total counts also include background counts.

Table 1. Total counts in the spectra for the data acquisition times of 100, 200 and 300 s (100, 200, 300 s'lik veri toplama süreleri için spektrumlardaki toplam sayımlar)

Time (s)	Real MCA	Virtual MCA
100	52743	54011
200	105552	102833
300	156554	153058

The beta energy spectra obtained from both MCAs for the acquisition time of 300 s is given in Figure 5. The image in Figure 5 (a) is the original screen view of the real MCA. In this figure, horizontal and vertical axes display the channel numbers and counts, respectively.
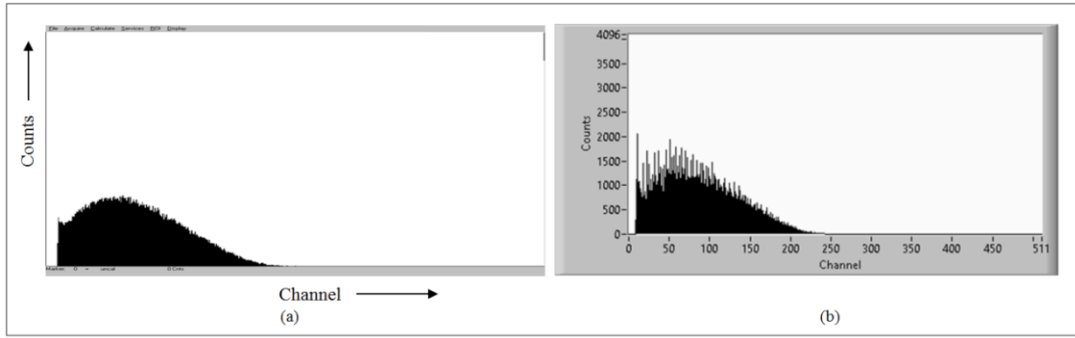
Figure 5. Spectrum shapes displayed in (a) real and (b) virtual MCAs for 300 s (300 s için (a) gerçek ve (b) sanal MCA'larda görüntülenen spektrum şekilleri)

In addition to the spectrum shape, the starting and ending channel numbers (ch. no.) were determined for each acquisition time in both MCAs for the comparison. These channel numbers are given in Table 2. The rows named 'Difference' in this table show the difference between the ending and starting channel numbers.

Table 2. Starting and ending channel numbers (ch. no.) obtained from both MCAs for the different acquisition times (Farklı veri toplama süreleri için her iki MCA'dan elde edilen başlangıç ve bitiş kanal numaraları(ch.no.))

	Time (s)	100	200	300
Real MCA	**Starting ch. no.**	12	12	12
	Ending ch. no.	248	257	263
	Difference	236	245	251
Virtual MCA	**Starting ch. no.**	9	9	9
	Ending ch. no.	245	256	273
	Difference	236	247	264

In addition to above, the output signals of the amplifier were displayed in the real and virtual oscilloscopes. Figure 6 shows the signal shapes displayed in these devices.
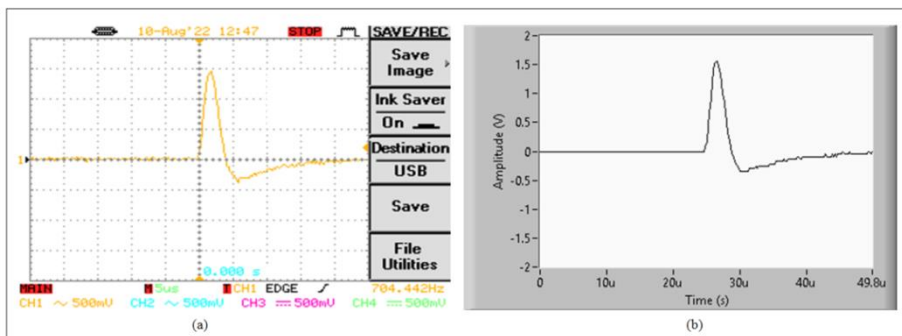

Figure 6. Signal shapes displayed in (a) real oscilloscope and (b) virtual oscilloscope ((a) Gerçek osiloskopta ve (b) sanal osiloskopta görüntülenen sinyal şekilleri)

4. DISCUSSION (TARTIŞMA)

A virtual MCA supported by a virtual oscilloscope was developed by writing a new code via LabVIEW software functions. It was also aimed to obtain the beta spectrum via the virtual MCA and to display the output signals of the amplifier from the detector in the virtual oscilloscope.

Radioactivity is a random event, i.e. the number of ionizing particle emitted by a radioactive substance per unit time is variable. For this reason, the number of counts in each channel of a MCA is different even if pulse amplitudes are the same in each measurement (i.e. the number of counts in the channels changes with each measurement). Since this is due to the radioactive decay, this situation is the same for the real MCA, too. Therefore, measurements were taken once for each data acquisition time. Besides, in order to test whether the total counts in the spectra obtained from both MCAs were compatible with each other, measurements were performed at three different data acquisition times. It was observed that these times were sufficient to display the beta spectra. When the data acquisition time is increased, the number of counts increases naturally, and this was observed in the experiment. As can be seen in the Table 1, the total counts obtained from both MCAs increased with the time increment. It was discerned that these counts from the virtual MCA were highly compatible with those of the real one. Since the operational principles of the real MCA are confidential business information, a detailed comment on the comparison about the counts could not be offered.

Beta particles have a continuous energy spectrum i.e. counts are recorded in each channel between starting and ending channel numbers [5]. This could be seen from the spectra from both MCAs (Figure 5). Besides, when the spectrum shapes displayed in the real and virtual MCAs were compared, it was noticed that they were compatible with each other. The reason of the little visual differences between the spectrum shapes is because the signal amplitudes were determined by the software function in the virtual MCA.

It was also investigated whether the starting and ending channel numbers determined from both MCAs were compatible with each other. It was realized from Table 2 that the existence of some differences between these channel numbers is due to the determination of the signal amplitudes through the software function in the virtual MCA again, as mentioned above.

By means of the equipped with oscilloscope feature of the virtual MCA, the amplifier signals through the digitizer are displayed on the virtual oscilloscope screen in addition to its multi-channeling feature. If you would like to track the signals together with the multi-channeling, however, you should use another real oscilloscope device apart from the real MCA. In this case, the virtual MCA has an advantage to the real ones because it does not need additional oscilloscope. Moreover, it can be deduced from the acquired signal evaluations that the developed virtual oscilloscope was operated likewise the real one (Figure 6). This result showed that the virtual oscilloscope could be used to display and determine the signal characteristics in place of the real oscilloscope.

The horizontal and vertical axis values and legends on the screens in the virtual MCA and the virtual oscilloscope are automatically given. The axis legends can be named by user (Figures 5 (b) and 6(b)) as well. These properties are another advantage of the virtual one in comparison to the real one.

A virtual MCA was developed for the gamma energy spectrum acquisition in ref. [9]. Differently from that study, it was examined here whether the beta energy spectrum with a completely different structure from the gamma energy spectrum could be obtained by the developed virtual MCA (i.e. while the beta energy spectrum has a continuous energy distribution as mentioned above, the gamma energy spectrum has a discrete structure, gamma photons emit at certain energies). Besides, in the virtual MCA introduced here, sample rate and number of sample required to obtain the data by the digitizer and "width", "threshold" and "peaks/valleys" inputs of "Peak Detector.vi" function could be set by the user via the controls in the front panel to acquire more compatible spectrum with the real one in different experimental studies (such as using different spectrometers or radioactive sources with different activity). It was concluded from the presented study that the developed virtual MCA could be used to obtain not only the gamma but only the beta spectra in educational and research studies.

5. CONCLUSIONS (SONUÇLAR)

A virtual MCA and a virtual oscilloscope were developed to acquire the spectra and display the signal shapes; and they were tested in a beta spectrometer. It was concluded from the experimental results that the developed virtual MCA could be used to accumulate the beta energy spectrum successfully. It was also observed that the virtual oscilloscope could be utilized for displaying the signals in nuclear spectrometers. It was deduced that the developed virtual MCA and the virtual oscilloscope could be operated in nuclear physics experiments as an alternative option to the real ones. In addition to this, the possibility of the additional features to the virtual MCA such as virtual oscilloscope brought about its advantage compared to the real one.

DECLARATION OF ETHICAL STANDARDS (ETİK STANDARTLARIN BEYANI)

The authors of this article declare that the materials and methods they use in their work do not require ethical committee approval and/or legal-specific permission.

Bu makalenin yazarları çalışmalarında kullandıkları materyal ve yöntemlerin etik kurul izni ve/veya yasal-özel bir izin gerektirmediğini beyan ederler.

AUTHORS' CONTRIBUTIONS (YAZARLARIN KATKILARI)

Gözde TEKTAŞ: She wrote the code by using LabVIEW software functions for virtual instruments, conducted the experiment and performed the writing process.

Sanal cihazlar için LabVIEW yazılım fonksiyonlarını kullanarak kod yazmış, deneyi yapmış ve yazım işlemini gerçekleştirmiştir.

Cüneyt ÇELİKTAŞ: He contributed to the code development for virtual instruments, conducted the experiment and performed the writing process.

Sanal cihazlar için kodun geliştirilmesine katkıda bulunmuş, deneyi yapmış ve yazım işlemini gerçekleştirmiştir.

CONFLICT OF INTEREST (ÇIKAR ÇATIŞMASI)

There is no conflict of interest in this study.

Bu çalışmada herhangi bir çıkar çatışması yoktur.

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