

ISSN 2518-170X (Online)
ISSN 2224-5278 (Print)

ҚАЗАҚСТАН РЕСПУБЛИКАСЫ
ҰЛТТЫҚ ҒЫЛЫМ АКАДЕМИЯСЫ

Satbayev University

Х А Б А Р Л А Р Ы

ИЗВЕСТИЯ

НАЦИОНАЛЬНОЙ АКАДЕМИИ
НАУК РЕСПУБЛИКИ
КАЗАХСТАН
Satbayev University

N E W S

OF THE ACADEMY OF SCIENCES
OF THE REPUBLIC OF
KAZAKHSTAN
Satbayev University

SERIES

OF GEOLOGY AND TECHNICAL SCIENCES

3 (459)

MAY – JUNE 2023

THE JOURNAL WAS FOUNDED IN 1940

PUBLISHED 6 TIMES A YEAR

ALMATY, NAS RK

NAS RK is pleased to announce that News of NAS RK. Series of geology and technical sciences scientific journal has been accepted for indexing in the Emerging Sources Citation Index, a new edition of Web of Science. Content in this index is under consideration by Clarivate Analytics to be accepted in the Science Citation Index Expanded, the Social Sciences Citation Index, and the Arts & Humanities Citation Index. The quality and depth of content Web of Science offers to researchers, authors, publishers, and institutions sets it apart from other research databases. The inclusion of News of NAS RK. Series of geology and technical sciences in the Emerging Sources Citation Index demonstrates our dedication to providing the most relevant and influential content of geology and engineering sciences to our community.

Қазақстан Республикасы Ұлттық ғылым академиясы «ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы» ғылыми журналының Web of Science-тің жаңаланған нұсқасы Emerging Sources Citation Index-те индекстелуге қабылданғанын хабарлайды. Бұл индекстелу барысында Clarivate Analytics компаниясы журналды одан әрі the Science Citation Index Expanded, the Social Sciences Citation Index және the Arts & Humanities Citation Index-ке қабылдау мәселесін қарастыруда. Web of Science зерттеушілер, авторлар, баспашылар мен мекемелерге контент тереңдігі мен сапасын ұсынады. ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы Emerging Sources Citation Index-ке енуі біздің қоғамдастық үшін ең өзекті және беделді геология және техникалық ғылымдар бойынша контентке адалдығымызды білдіреді.

НАН РК сообщает, что научный журнал «Известия НАН РК. Серия геологии и технических наук» был принят для индексирования в Emerging Sources Citation Index, обновленной версии Web of Science. Содержание в этом индексировании находится в стадии рассмотрения компанией Clarivate Analytics для дальнейшего принятия журнала в the Science Citation Index Expanded, the Social Sciences Citation Index и the Arts & Humanities Citation Index. Web of Science предлагает качество и глубину контента для исследователей, авторов, издателей и учреждений. Включение Известия НАН РК. Серия геологии и технических наук в Emerging Sources Citation Index демонстрирует нашу приверженность к наиболее актуальному и влиятельному контенту по геологии и техническим наукам для нашего сообщества.

Бас редактор

ЖҰРЫНОВ Мұрат Жұрынұлы, химия ғылымдарының докторы, профессор, ҚР ҰҒА академигі, Қазақстан Республикасы Ұлттық Ғылым академиясының президенті, АҚ «Д.В. Сокольский атындағы отын, катализ және электрохимия институтының» бас директоры (Алматы, Қазақстан) **Н = 4**

Ғылыми хатшы

АБСАДЫКОВ Бахыт Нарикбайұлы, техника ғылымдарының докторы, профессор, ҚР ҰҒА жауапты хатшысы, А.Б. Бектұров атындағы химия ғылымдары институты (Алматы, Қазақстан) **Н = 5**

Редакциялық алқа:

ӘБСАМЕТОВ Мәліс Құдысұлы (бас редактордың орынбасары), геология-минералогия ғылымдарының докторы, профессор, ҚР ҰҒА академигі, «У.М. Ахмедсафина атындағы гидрогеология және геоэкология институтының» директоры (Алматы, Қазақстан) **Н = 2**

ЖОЛТАЕВ Герой Жолтайұлы (бас редактордың орынбасары), геология-минералогия ғылымдарының докторы, профессор, Қ.И. Сатпаев атындағы геология ғылымдары институтының директоры (Алматы, Қазақстан) **Н = 2**

СНОУ Дэниел, Ph.D, қауымдастырылған профессор, Небраска университетінің Су ғылымдары зертханасының директоры (Небраска штаты, АҚШ) **Н = 32**

ЗЕЛЬТМАН Реймар, Ph.D, табиғи тарих мұражайының Жер туралы ғылымдар бөлімінде петрология және пайдалы қазбалар кен орындары саласындағы зерттеулердің жетекшісі (Лондон, Англия) **Н = 37**

ПАНФИЛОВ Михаил Борисович, техника ғылымдарының докторы, Нанси университетінің профессоры (Нанси, Франция) **Н = 15**

ШЕН Пин, Ph.D, Қытай геологиялық қоғамының тау геологиясы комитеті директорының орынбасары, Американдық экономикалық геологтар қауымдастығының мүшесі (Пекин, Қытай) **Н = 25**

ФИШЕР Аксель, Ph.D, Дрезден техникалық университетінің қауымдастырылған профессоры (Дрезден, Берлин) **Н = 6**

КОНТОРОВИЧ Алексей Эмильевич, геология-минералогия ғылымдарының докторы, профессор, РҒА академигі, А.А. Трофимука атындағы мұнай-газ геологиясы және геофизика институты (Новосибирск, Ресей) **Н = 19**

АГАБЕКОВ Владимир Енокович, химия ғылымдарының докторы, Беларусь ҰҒА академигі, Жаңа материалдар химиясы институтының құрметті директоры (Минск, Беларусь) **Н = 13**

КАТАЛИН Стефан, Ph.D, Дрезден техникалық университетінің қауымдастырылған профессоры (Дрезден, Берлин) **Н = 20**

СЕЙТМҰРАТОВА Элеонора Юсуповна, геология-минералогия ғылымдарының докторы, профессор, ҚР ҰҒА корреспондент-мүшесі, Қ.И. Сатпаев атындағы Геология ғылымдары институты зертханасының меңгерушісі (Алматы, Қазақстан) **Н = 11**

САҒЫНТАЕВ Жанай, Ph.D, қауымдастырылған профессор, Назарбаев университеті (Нұр-Сұлтан, Қазақстан) **Н = 11**

ФРАТТИНИ Паоло, Ph.D, Бикокк Милан университеті қауымдастырылған профессоры (Милан, Италия) **Н = 28**

«ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы».

ISSN 2518-170X (Online),

ISSN 2224-5278 (Print)

Меншіктеуші: «Қазақстан Республикасының Ұлттық ғылым академиясы» РҚБ (Алматы қ.).

Қазақстан Республикасының Ақпарат және қоғамдық даму министрлігінің Ақпарат комитетінде 29.07.2020 ж. берілген № **KZ39VPY00025420** мерзімдік басылым тіркеуіне қойылу туралы куәлік.

Тақырыптық бағыты: *геология, мұнай және газды өңдеудің химиялық технологиялары, мұнай химиясы, металдарды алу және олардың қосындыларының технологиясы.*

Мерзімділігі: жылына 6 рет.

Тиражы: 300 дана.

Редакцияның мекен-жайы: 050010, Алматы қ., Шевченко көш., 28, 219 бөл., тел.: 272-13-19

<http://www.geolog-technical.kz/index.php/en/>

© Қазақстан Республикасының Ұлттық ғылым академиясы, 2023

Типографияның мекен-жайы: «Аруна» ЖК, Алматы қ., Мұратбаев көш., 75.

Главный редактор

ЖУРИНОВ Мурат Журинович, доктор химических наук, профессор, академик НАН РК, президент Национальной академии наук Республики Казахстан, генеральный директор АО «Институт топлива, катализа и электрохимии им. Д.В. Сокольского» (Алматы, Казахстан) **Н = 4**

Ученый секретарь

АБСАДЫКОВ Бахыт Нарикбаевич, доктор технических наук, профессор, ответственный секретарь НАН РК, Институт химических наук им. А.Б. Бектурова (Алматы, Казахстан) **Н = 5**

Редакционная коллегия:

АБСАМЕТОВ Малис Кудысович, (заместитель главного редактора), доктор геологоминералогических наук, профессор, академик НАН РК, директор Института гидрогеологии и геоэкологии им. У.М. Ахмедсафина (Алматы, Казахстан) **Н = 2**

ЖОЛТАЕВ Герой Жолтаевич, (заместитель главного редактора), доктор геологоминералогических наук, профессор, директор Института геологических наук им. К.И. Сатпаева (Алматы, Казахстан) **Н = 2**

СНОУ Дэниел, Ph.D, ассоциированный профессор, директор Лаборатории водных наук университета Небраски (штат Небраска, США) **Н = 32**

ЗЕЛЬТМАН Реймар, Ph.D, руководитель исследований в области петрологии и месторождений полезных ископаемых в Отделе наук о Земле Музея естественной истории (Лондон, Англия) **Н = 37**

ПАНФИЛОВ Михаил Борисович, доктор технических наук, профессор Университета Нанси (Нанси, Франция) **Н = 15**

ШЕН Пин, Ph.D, заместитель директора Комитета по горной геологии Китайского геологического общества, член Американской ассоциации экономических геологов (Пекин, Китай) **Н = 25**

ФИШЕР Аксель, ассоциированный профессор, Ph.D, технический университет Дрезден (Дрезден, Берлин) **Н = 6**

КОНТОРОВИЧ Алексей Эмильевич, доктор геолого-минералогических наук, профессор, академик РАН, Институт нефтегазовой геологии и геофизики им. А.А. Трофимука СО РАН (Новосибирск, Россия) **Н = 19**

АГАБЕКОВ Владимир Енокович, доктор химических наук, академик НАН Беларуси, почетный директор Института химии новых материалов (Минск, Беларусь) **Н = 13**

КАТАЛИН Стефан, Ph.D, ассоциированный профессор, Технический университет (Дрезден, Берлин) **Н = 20**

СЕЙТМУРАТОВА Элеонора Юсуповна, доктор геолого-минералогических наук, профессор, член-корреспондент НАН РК, заведующая лабораторией Института геологических наук им. К.И. Сатпаева (Алматы, Казахстан) **Н = 11**

САГИНТАЕВ Жанай, Ph.D, ассоциированный профессор, Назарбаев университет (Нурсултан, Казахстан) **Н = 11**

ФРАТТИНИ Паоло, Ph.D, ассоциированный профессор, Миланский университет Бикокк (Милан, Италия) **Н = 28**

«Известия НАН РК. Серия геологии и технических наук».

ISSN 2518-170X (Online),

ISSN 2224-5278 (Print)

Собственник: Республиканское общественное объединение «Национальная академия наук Республики Казахстан» (г. Алматы).

Свидетельство о постановке на учет периодического печатного издания в Комитете информации Министерства информации и общественного развития Республики Казахстан № **KZ39VPY00025420**, выданное 29.07.2020 г.

Тематическая направленность: *геология, химические технологии переработки нефти и газа, нефтехимия, технологии извлечения металлов и их соединений.*

Периодичность: 6 раз в год.

Тираж: 300 экземпляров.

Адрес редакции: 050010, г. Алматы, ул. Шевченко, 28, оф. 219, тел.: 272-13-19

<http://www.geolog-technical.kz/index.php/en/>

© Национальная академия наук Республики Казахстан, 2023

Адрес типографии: ИП «Аруна», г. Алматы, ул. Муратбаева, 75.

Editorial chief

ZHURINOV Murat Zhurinovich, doctor of chemistry, professor, academician of NAS RK, president of the National Academy of Sciences of the Republic of Kazakhstan, general director of JSC "Institute of fuel, catalysis and electrochemistry named after D.V. Sokolsky" (Almaty, Kazakhstan) **H = 4**

Scientific secretary

ABSADYKOV Bakhyt Narikbaevich, doctor of technical sciences, professor, executive secretary of NAS RK, Bekturov Institute of chemical sciences (Almaty, Kazakhstan) **H = 5**

Editorial board:

ABSAMETOV Malis Kudysovich, (deputy editor-in-chief), doctor of geological and mineralogical sciences, professor, academician of NAS RK, director of the Akhmedsafin Institute of hydrogeology and hydrophysics (Almaty, Kazakhstan) **H=2**

ZHOLTAEV Geroy Zholtaevich, (deputy editor-in-chief), doctor of geological and mineralogical sciences, professor, director of the institute of geological sciences named after K.I. Satpayev (Almaty, Kazakhstan) **H=2**

SNOW Daniel, Ph.D, associate professor, director of the laboratory of water sciences, Nebraska University (Nebraska, USA) **H = 32**

ZELTMAN Reyman, Ph.D, head of research department in petrology and mineral deposits in the Earth sciences section of the museum of natural history (London, England) **H = 37**

PANFILOV Mikhail Borisovich, doctor of technical sciences, professor at the Nancy University (Nancy, France) **H=15**

SHEN Ping, Ph.D, deputy director of the Committee for Mining geology of the China geological Society, Fellow of the American association of economic geologists (Beijing, China) **H = 25**

FISCHER Axel, Ph.D, associate professor, Dresden University of technology (Dresden, Germany) **H=6**

KONTOROVICH Aleksey Emilievich, doctor of geological and mineralogical sciences, professor, academician of RAS, Trofimuk Institute of petroleum geology and geophysics SB RAS (Novosibirsk, Russia) **H = 19**

AGABEKOV Vladimir Enokovich, doctor of chemistry, academician of NAS of Belarus, honorary director of the Institute of chemistry of new materials (Minsk, Belarus) **H = 13**

KATALIN Stephan, Ph.D, associate professor, Technical university (Dresden, Berlin) **H = 20**

SEITMURATOVA Eleonora Yusupovna, doctor of geological and mineralogical sciences, professor, corresponding member of NAS RK, head of the laboratory of the Institute of geological sciences named after K.I. Satpayev (Almaty, Kazakhstan) **H=11**

SAGINTAYEV Zhanay, Ph.D, associate professor, Nazarbayev University (Nursultan, Kazakhstan) **H = 11**

FRATTINI Paolo, Ph.D, associate professor, university of Milano-Bicocca (Milan, Italy) **H = 28**

News of the National Academy of Sciences of the Republic of Kazakhstan. Series of geology and technology sciences.

ISSN 2518-170X (Online),

ISSN 2224-5278 (Print)

Owner: RPA «National Academy of Sciences of the Republic of Kazakhstan» (Almaty).

The certificate of registration of a periodical printed publication in the Committee of information of the Ministry of Information and Social Development of the Republic of Kazakhstan **No. KZ39VPY00025420**, issued 29.07.2020.

Thematic scope: *geology, chemical technologies for oil and gas processing, petrochemistry, technologies for extracting metals and their connections.*

Periodicity: 6 times a year.

Circulation: 300 copies.

Editorial address: 28, Shevchenko str., of. 219, Almaty, 050010, tel. 272-13-19

<http://www.geolog-technical.kz/index.php/en/>

© National Academy of Sciences of the Republic of Kazakhstan, 2023

Address of printing house: ST «Aruna», 75, Muratbayev str, Almaty.

NEWS of the National Academy of Sciences of the Republic of Kazakhstan
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5278
Volume 3, Number 459 (2023), 47–59
<https://doi.org/10.32014/2023.2518-170X.298>

UDK 621.396.6

©A.A. Yerzhan¹, P.V. Boikachev², B.R. Nakisbekova^{1*}, Z.D. Manbetova³,
P.A. Dunayev³, 2023

¹Almaty University of Power Engineering and Telecommunications named after
Gumarbek Daukeev, Almaty, Kazakhstan;

² Educational Institution "Military Academy of the Republic of Belarus",
Minsk, Belarus;

³ NCJSC «S. Seifullin Kazakh Agrotechnical Research University»,
Astana, Kazakhstan.

E-mail: b.nakisbekova@aes.kz

METHOD OF SYNTHESIS OF MATCHING TELECOMMUNICATION DEVICES BASED ON THE METHOD OF REAL FREQUENCIES FOR 5G ANTENNAS IN A DISTRIBUTED ELEMENT BASIS

Yerzhan Assel — PhD. Department "Telecommunications and Innovative Technologies", Almaty University of Power Engineering and Telecommunications named after Gumarbek Daukeev, Almaty, Kazakhstan

<https://orcid.org/0000-0003-3533-1371>. E-mail: a.erzhan@aes.kz;

Boikachev Pavel — Educational Institution "Military Academy of the Republic of Belarus", 220 Nezavisimosti Ave., Minsk, 220057, Belarus

<https://orcid.org/0000-0003-2873-9192>. E-mail: pashapasha.boi@mail.ru;

Nakisbekova Balausa — doctoral student, Department "Telecommunications and Innovative Technologies", Almaty University of Power Engineering and Telecommunications named after Gumarbek Daukeev, Almaty, Kazakhstan.,

<https://orcid.org/0000-0003-4084-0402>. E-mail: b.nakisbekova@aes.kz;

Manbetova Zhanat — PhD., Department of Radio Engineering, Electronics and Telecommunications, NCJSC «S. Seifullin Kazakh Agrotechnical Research University», Astana

<https://orcid.org/0000-0002-6716-4646>. E-mail: zh.manbetova@kazatu.kz;

Dunayev Pavel — Candidate of Technical Sciences, PhD, acting Associate Professor, Head of the Department of Radio Engineering, Electronics and Telecommunications, NCJSC «S. Seifullin Kazakh Agrotechnical Research University», Astana

<https://orcid.org/0000-0003-0379-315X>. E-mail: dunayev.kz@mail.ru.

Abstract. To solve the problem of synthesizing load matching circuits in a distributed element basis, the complex resistance of which has a non-stationary character in a wide band of operating frequencies, a new matching technique based on the sensitivity invariant apparatus in combination with the Richards and Kuroda transformation has been developed. The verification of the methodology was carried out on the example of matching the active element with the output and input loads in

Mitsubishi's LD-MOSRD07 power amplifiers. Radio engineering devices (RTU) are widely used in almost all spheres of human activity. In order for the RTU to provide maximum energy efficiency, and as a consequence, the maximum range of the radio line in various operating conditions, it is necessary that the elements of the radio engineering paths of both the transmitting and receiving devices, having their complex resistance (varying over time), be coordinated with each other. To perform this task, broadband matching devices (SHSU) are used, the synthesis methods of which do not take into account the variability of the load impedance caused by changes in operating conditions (temperature, vibration, various modes of operation of active elements, etc.). As a result, there is a need to develop a method for the synthesis of SHSU that provides a stable level of power transmission in conditions of varying load impedance. Such a need is relevant for RTU in both concentrated and distributed element basis. The paper proposes a method for the synthesis of matching devices for a distributed element basis. Geology is a multifaceted science that is classified into many areas, depending on the subject of research, analysis technology, subjects of study, theoretical calculations or the scope of application of knowledge obtained in the course of complex research. The most common aspects of geology as a science, their practical or applied application and benefits for humanity in modern life are described in detail below.

Keywords: 5G antenna, radio engineering device, load resistance, radio line, operating frequency

Financing. The work was carried out with financial support under the grant of the President of the Republic of Belarus in the fields of science, education, health, culture, youth policy. In accordance with the Decree of the President of the Republic of Belarus dated September 13, 2013 № 425.

©А.А. Ержан¹, П.В. Бойкачев², Б.Р. Накисбекова^{1*}, Ж.Д. Манбетова³,
П.А. Дунаев³, 2023

¹Ғұмарбек Даукеев атындағы Алматы энергетика және байланыс университеті,
Алматы, Қазақстан;

²Беларусь Әскери Академиясы, Минск, Беларусь;

³«С.Сейфуллин атындағы Қазақ агротехникалық зерттеу университеті» КеАҚ,
Астана, Қазақстан.

E-mail: b.nakisbekova@aes.kz

ҮЛЕСТІРІЛГЕН ЭЛЕМЕНТ БАЗАСЫНДА 5 G АНТЕННАЛАР ҮШІН НАҚТЫ ЖИІЛІК ӘДІСІ НЕГІЗІНДЕ КЕЛІСЕТІН ТЕЛЕКОММУНИКАЦИЯЛЫҚ ҚҰРЫЛҒЫЛАРДЫ СИНТЕЗДЕУ ӘДІСТЕМЕСІ

Аннотация. Кешенді кедергісі жұмыс жиіліктерінің кең ауқымында стационарлық емес сипатта болатын үлестірілген элементтер базасында жүктемені үйлестіру схемаларын синтездеу мәселесін шешу үшін Ричардс пен Куродтың түрлендіруімен сезімталдыққа инвариантты аппаратқа негізделген

сәйкестендірудің жаңа әдісі жасалды. Әдістемені тексеру Mitsubishi LD-MOSRD07 қуат күшейткіштеріндегі белсенді элементті Шығыс және кіріс жүктемелерімен үйлестіру мысалында жүргізілді. Радиотехникалық құрылғылар (RTU) адам қызметінің барлық салаларында кеңінен қолданылады. Өзінің кешенді кедергісі бар (уақыт бойынша өзгеретін) таратушы және қабылдаушы құрылғылардың радиотехникалық трактілерінің элементтері RTU максималды энергия тиімділігін және соның салдарынан әртүрлі пайдалану жағдайларында радиолиниялардың максималды диапазонын қамтамасыз ету үшін бір-бірімен келісілуі тиіс. Бұл тапсырманы орындау үшін синтездеу әдістері жұмыс жағдайларының (температура, діріл, белсенді элементтердің әртүрлі жұмыс режимдері және т.б.) өзгеруінен туындаған жүктеме кедергісінің өзгергіштігін ескермейтін кең жолақты келісу құрылғылары (ШСУ) қолданылады. Нәтижесінде жүктеменің өзгермелі кедергісі жағдайында қуат берудің тұрақты деңгейін қамтамасыз ететін CFC синтездеу әдісін әзірлеу қажет болады. Бұл қажеттілік шоғырландырылған және үлестірілген элементтер базасындағы RTU үшін маңызды. Мақалада үлестірілген элементтер базасында тиісті құрылғыларды синтездеу әдісі ұсынылған. Геология-бұл кең Ғылыми тұжырымдама, оның құрамына қолданбалы қолдану саласы, теориялық есептеулер категориясы, төменде егжей-тегжейлі сипатталған зерттеу объектілерінің түрі бойынша ерекшеленетін көптеген бөлімдер кіреді.

Түйін сөздер: 5G антеннасы, радиотехникалық құрылғы, жүктеме кедергісі, радио желісі, жұмыс жиілігі

©А.А. Ержан¹, П.В. Бойкачев², Б.Р. Накисбекова^{1*}, Ж.Д. Манбетова³,
П.А. Дунаев³, 2023

¹Алматинский университет энергетики и связи имени Гумарбека Даукеева,
Алматы, Казахстан;

²Военная Академия Беларуси, Минск, Беларусь;

³НАО «Казахский агротехнический исследовательский университет
им. С. Сейфуллина» Астана, Казахстан.

E-mail: b.nakisbekova@aes.kz.

МЕТОДИКА СИНТЕЗА СОГЛАСУЮЩИХ ТЕЛЕКОММУНИКАЦИОННЫХ УСТРОЙСТВ НА ОСНОВЕ МЕТОДА Вещественных частот для 5 G антенн в распределенном ЭЛЕМЕНТНОМ БАЗИСЕ

Ержан Асел Ануарқызы — доктор PhD., доцент кафедры Телекоммуникации и инновационных технологий, Алматинский университет энергетики и связи имени Гумарбека Даукеева, Алматы, Казахстан

<https://orcid.org/0000-0003-3533-1371>. E-mail: a.erzhan@aes.kz;

Бойкачев Павел Валерьевич — заведующий кафедрой, УО "Военная академия Республики Беларусь", 220057, Беларусь, г. Минск, пр. Независимости, 220

<https://orcid.org/0000-0003-2873-9192>. E-mail: pashapasha.boi@mail.ru;

Накисбекова Балауса Рысқожаевна — докторант, кафедры Телекоммуникации и инновационных технологий, Алматинский университет энергетики и связи имени Гумарбека Даукеева, Алматы, Казахстан

<https://orcid.org/0000-0003-4084-0402>. E-mail: b.nakisbekova@au.es.kz;

Манбетова Жанат Дусенбаевна — доктор PhD, старший преподаватель кафедры радиотехники, электроники и телекоммуникаций НАО «Казахский агротехнический исследовательский университет им. С. Сейфуллина», Астана

<https://orcid.org/0000-0002-6716-4646>. E-mail: zh.manbetova@kazatu.kz;

Дунаев Павел Александрович — кандидат технических наук, PhD, заведующий кафедрой Радиотехники, электроники и телекоммуникаций НАО «Казахский агротехнический исследовательский университет им. С. Сейфуллина», Астана

<https://orcid.org/0000-0003-0379-315X>. E-mail: dunayev.kz@mail.ru.

Аннотация. Для решения задачи синтеза схем координации нагрузки на распределенной элементной базе, комплексное сопротивление которой носит нестационарный характер в широком диапазоне рабочих частот был разработан новый метод идентификации, основанный на аппарате, инвариантном к чувствительности, с преобразованием Ричардса и Курода. Проверка методики проводилась на примере согласования активного элемента в усилителях мощности Mitsubishi LD-MOSRD07 с выходными и входными нагрузками. Радиотехнические устройства (RTU) широко используются во всех сферах человеческой деятельности. Элементы радиотехнических трактов передающих и принимающих устройств со своим комплексным сопротивлением (изменяющимся во времени) должны быть согласованы друг с другом, чтобы обеспечить максимальную энергоэффективность RTU и, как следствие, максимальный диапазон радиолиний в различных условиях эксплуатации. Для выполнения этой задачи используются широкополосные согласующие устройства (ШСУ), методы синтеза которых не учитывают изменчивость сопротивления нагрузки, вызванную изменением условий работы (температуры, вибрации, различных режимов работы активных элементов и др.). В результате возникает необходимость разработки метода синтеза ХФУ, обеспечивающего стабильный уровень передачи мощности в условиях переменного сопротивления нагрузки. Эта потребность важна для RTU в консолидированной и распределенной элементной базе. В статье предлагается метод синтеза соответствующих устройств на распределенной элементной базе. Геология — это обширная научная концепция, которая включает в себя область прикладного применения, категорию теоретических расчетов, множество разделов, различающихся по типу объектов исследования, подробно описанных ниже.

Ключевые слова: антенна 5G, радиотехническое устройство, сопротивление нагрузки, радиолиния, рабочая частота

Introduction

A review and analysis of broadband matching methods have shown that it is advisable to use the method of real frequencies as a mathematical apparatus for the synthesis of a matching circuit (MC) with varying load impedance (Dubovik et al., 2021).

It is proposed to develop a method for the synthesis of BMD that provide the required level of power transmission under conditions of varying load impedance for RED in a

distributed element basis based on the method of real frequencies in combination with the Richards and Kuroda transformation.

It should be noted that the spread of the nominal values of the BMD elements (in a distributed element basis, the dimensions, magnetic and dielectric permittivity of the substrates, etc.) and the load connected to it negatively affect the functioning of the RED in various operating conditions. The connection between the space of circuit parameters, analysis and optimization, including with adjustable (controlled) parameters, can be carried out using the sensitivity function. This function can contribute to solving a wide range of tasks related to the analysis of the impact of small changes in design parameters and external conditions on the operation of RED.

For the synthesis of the BMD, which allows to ensure the level of the power gain (PG) is not worse than required, in the presence of a changing load impedance, first of all it is necessary to assess the degree of influence of the load impedance variation on the PG level. Let's imagine the complex load resistance as a number of parameters ($i = 1, 2, \dots, M$), on which a certain function describing the frequency response of the BMD (PG, group delay time, etc.) depends. The deviation of the function from the nominal value caused by a change in the parameter is determined by the corresponding Taylor series expansion. For the linearized case (we neglect the derivatives of the second and higher orders), the decomposition has the form

$$S_{x_i}^D = S\{D(x_i), x_i\} = \sum_{i=1}^N \frac{\partial D(x_i)}{\partial x_i} \quad (1)$$

where $S_{x_i}^D = S\{D(x_i), x_i\} = \sum_{i=1}^N \frac{\partial D(x_i)}{\partial x_i}$ - sensitivity of the function to parameter changes

- number of parameters;
- function deviation.

Expression (1) is used to describe the effect of small deviations, and it is based on mathematical analysis. Of particular interest in this expression is the sensitivity of the BMD characteristic, since a decrease in the value of this parameter leads to a decrease in the deviation of the BMD characteristic, and with its fixed (permissible) value increases the deviation, at which the required values of the BMD characteristic are preserved (Dedus et al., 2004).

To ensure the required level of PG in the presence of a changing load impedance, it is necessary that the synthesized BMD has the property of minimal sensitivity of the reflection coefficient function to changes in load parameters. To do this, it is necessary to solve a system of equations

$$\begin{cases} \int_{f_n}^{f_H} \left(K_{\text{треб}} - \left(1 - |S_{in}(f, Z_H, Z_{\text{CL}})|^2 \right) \right)^2 df \leq \varepsilon \\ \int_{f_H}^{f_n} \left| \text{Re} \left\{ R \left\{ S_{in}(f, Z_H, Z_{\text{CL}}) \right\} \right\} \right|^2 df \leq \min \end{cases} \quad (2)$$

where K_{req} - required level of PG; $Z_H(f)$ - complex payload resistance;
 $Z_{cl}(f)$ - complex resistance of the matching circuit;

$$R\{S_{in}(f, Z_H, Z_{cl})\} = \frac{2 \operatorname{Re}\{Z_{cl}(f)\} Z_H(f)}{(Z_H(f) + Z_{cl}(f))(Z_H(f) - Z_{cl}(-f))} - \text{invariant of the sensitivity}$$

of the reflection coefficient function to changes in payload parameters;

$$S_{in}(f, Z_H, Z_{cl}) = \frac{Z_H(f) - Z_{cl}(-f)}{Z_H(f) + Z_{cl}(f)} - \text{reflection coefficient function (mismatch}$$

coefficient); - permissible deviation of the PG level in the operating frequency range.

To determine the minimum value of the sensitivity invariant, it is proposed to use the expression 3.

$$\delta = \int_{f_B}^{f_H} \frac{\Delta |S_{in}(f, Z_H, Z_{cl})|}{|S_{in}(f, Z_H, Z_{cl})|} \left| \frac{Z_H}{(\Delta \operatorname{Re}\{Z_H\} + i \Delta \operatorname{Im}\{Z_H\})} \right| df \quad (3)$$

where $\Delta |S_{in}(f, Z_H, Z_{cl})|$ - permissible deviation of the reflection coefficient function module;

$\Delta \operatorname{Re}\{Z_H\}, i \Delta \operatorname{Im}\{Z_H\}$ - permissible deviation of the real, imaginary part of the reflection coefficient function.

Thus, the system of equations is transformed to the form

$$\left\{ \begin{array}{l} \int_{f_B}^{f_H} \left(K_{\text{треб}} - \left(1 - |S_{in}(f, Z_H, Z_{cl})|^2 \right) \right)^2 df \leq \varepsilon \\ \int_{f_H}^{f_B} \left| \operatorname{Re}\{R\{S_{in}(f, Z_H, Z_{cl})\}\} \right|^2 df \leq \delta \end{array} \right. \quad (4)$$

where the initial data is given: the required deviation of the PG level, the permissible deviation of the modulus of the reflection coefficient function, the deviation of the complex load resistance ($\Delta \operatorname{Re}\{Z_H\}, \Delta \operatorname{Im}\{Z_H\}$).

The system of equations can be used as an objective function (complex criterion) in combination with one of the existing numerical methods for the synthesis of BMD. It is proposed to use the method of real frequencies as a method of BMD synthesis. The main advantage of this method is that it does not require an approximation of the load impedance, and also that the PG function is represented as an analytical expression, while the ladder structure of the BMD is synthesized using iterative approaches to search for the real component of the resistance function of the BMD (Boykachev et al., 2012; Cherdyntsev et al., 2010). Thus, the combination of a complex criterion with the method of real frequencies 5G type of the real component of the resistance function allowed us to develop a method for the synthesis of matching devices for broadband radio engineering devices to a changing load impedance in a distributed element basis, which is shown in Fig. 1.

The developed methodology consists of seven stages:

To simplify the subsequent calculations, the input data (complex load resistance and frequency) is normalized, presented in the form of discrete samples. Based on the required level of PG and the permissible deviation of the load impedance in the operating frequency range, as well as the order of the electrical circuit;

The procedure for forming the form of the real component of the resistance function of the MC and the formation algorithm.

Formation of a complex representation of the function;

Calculation of the PG level taking into account the resistance function of the matching circuit;

Calculation of the sensitivity invariant of the reflection coefficient function module, as well as the minimum possible value of the sensitivity invariant in the operating frequency band;

Depending on the type of matching problem, one of the optimality criteria is calculated, according to the value of which a decision is made to recalculate the coefficients of the auxiliary polynomial. If the optimality criterion is met, proceed to the seventh stage of synthesis;

Formation of the complex resistance function of the MC with its subsequent transfer to the Richards (Fano et al., 1965; Orazbayev et al., 2012) space and synthesis of microstrip lines from the formed function;

Replacement of physically unrealizable elements with Kuroda elements (Filippovich et al., 1965; Filippovich et al., 2021)

The advantage of this approach lies in the absence of differentiation of the reflection coefficient function to find the sensitivity value. It is enough only to know the value of the SD impedance at a discrete range of frequencies in order to synthesize a BMD with minimal sensitivity to changes in the load impedance in a distributed element basis.

Analysis of quality indicators of the obtained mathematical model of adaptive matching device.

After the development of the BMD synthesis technique followed by the synthesis of the matching chain in combination with RFPA, Richards and Kuroda transformations, it is necessary to check the operability of this technique. To verify the presented methodology, it is proposed to develop a broadband impedance transformer based on it, designed for the Mitsubishi LD-MOSRD07 power amplifier. (Alekseeva et al., 1987; Moldasheva et al., 2022).

Synthesis of MC for Mitsubishi LD-MOSRD07 power amplifier.

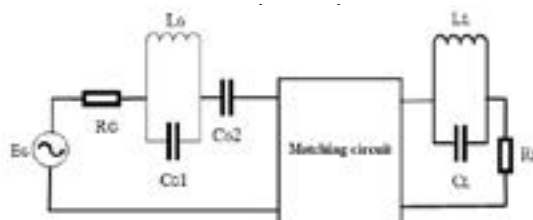


Fig. 1 The task of double matching of the LD-MOSRD07 power amplifier

Referring to Fig. 1, the impedance conversion filter is built between the generator $R_G = 12$ ohms (the output of the HF power amplifier, which is designed using Mitsubishi's LD-MOSRD07).

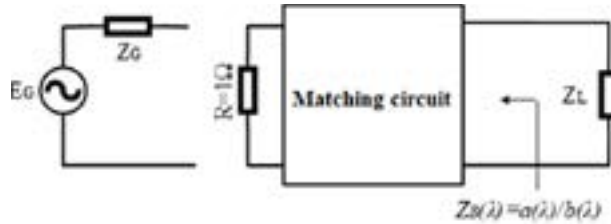


Fig. 2 Description of the matching network using the input resistance from the $Z_B(\lambda)$ side

Standard load $R_L = 50$ ohms in the range of 850-2100 MHz. On the oscillator side (12 ohms), the LG//CG1 resonant circuit introduces zero transmission at a frequency of 4200 GHz, which is the second harmonic at the upper end of the bandwidth. In addition, C_G2 introduces zero DC transmission. Similarly, on the load side, the LL//CL oscillatory circuit introduces zero transmission at the third harmonic (6300 MHz). Thus, Figure 2 shows the problem of double matching (complex resistance on both sides). The matching circuit must ensure coordination between the complex generator Z_G and the complex load Z_L .

Let's set the initial parameters of the loads $R_G = 12$ ohms, $L_G = 0.947$ nGn, $C_G1 = 1.515$ pF, $C_G2 = 3.4$ pF, $C_L = 1.515$ pF, $L_L = 0.412$ nGn, $R_L = 50$ ohms.

The matching circuit is synthesized, providing matching resistance from $Z_B(\lambda)$ using six commensurate transmission lines ($n = 6$). During the design, $k = 4$ (the total number of cascades) and $q = 0$ (without zero DC transmission) are selected, which, in turn, gives $n \infty = k - q = 2$ transmission zeros at infinity.

The coefficients of the auxiliary polynomial are initialized. In addition, c_0 is fixed equal to one ($c_0 = 1$), so that the normalized terminal resistance R is set equal to one. Thus, a fractional rational function describing the resistance $Z_B(\lambda)$ obtained by the presented method will have the form:

$$Z_B(\lambda) = \frac{a(\lambda)}{b(\lambda)} = \frac{0\lambda^6 + 0.62\lambda^5 + 0.7259\lambda^4 + 0.2427\lambda^3 + 0.1717\lambda^2 + 0.0169\lambda + 0.0036}{2.1530\lambda^6 + 2.5204\lambda^5 + 1.1745\lambda^4 + 0.9848\lambda^3 + 0.1634\lambda^2 + 0.0754\lambda + 0.0036} \quad (5)$$

The coefficients are obtained as a result of optimization, and the coefficients of the numerator polynomial and the denominator polynomial are obtained using the Levenberg-Marquardt method (Yarman et al., 2010; Gorshelev et al., 1977).

Table 1. Calculation results

N_0	$c(\Omega), *100$	$a(\lambda)$	$a(\lambda)$
	5,9257	0	2,1529
	6,0851	0,6200	2,5204
	-2,2964	0,7258	1,1744

	-2,3805	0,2426	0,9844
	0,1579	0,1717	0,1634
	0,1757	0,0168	0,0753
	0,010	0,0036	0,0036

After finding the function $Z_B(\lambda)$ with normalized parameters $R_0 = 1$, $f_0 = 1/(2\pi)$, perform the Richards transform.

The list of output vectors is shown in Table 2, and the final synthesis of $Z_B(\lambda)$ is shown in Figure 4.

Table 2. Synthesis results for the Richards transformation

N_0	Z_{new}	a_{new}	b_{new}	CT	CV
	0.2517	0	1.0000	8	7.5637
	1.8721	0.1322	1.1706	1	0.8542
	0.1245	0.1547	0.1547	9	0.9999
	1.536	-	-	-	-

where Z_{new} - normalized wave resistance; a_{new} , b_{new} — recalculated values of the coefficients of the numerator, denominator of the resistance function; CT is the type of connection of the MC cascade and the type of radio element (CT = 1 – serial Richards inductance, 8 – parallel Richards capacitance, 9 – resistor); CV — the remainder of the division.

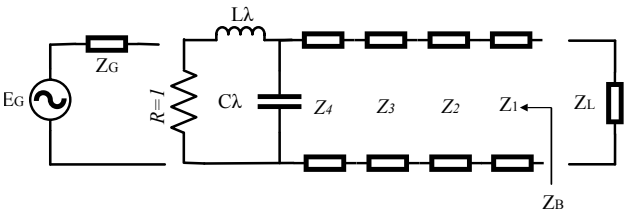


Fig. 3 – Results of the synthesis of MC from $Z_B(\lambda)$

Thus, the wave resistance in Fig. 3 is determined by the expression

$$Z_1 = 0.2517; Z_2 = 1.8721; Z_3 = 0.1246; Z_4 = 1.5364,$$

and the Richards components are listed as:

$$C = 7,5637; L = 0,8542.$$

When choosing the number of resistance normalization $R_0 = 50$ ohms, the actual values of the elements are determined as

$$Z_{\text{new}} = [12,5850 \quad 93,6052 \quad 6,2297 \quad 76,8177];$$

The Richards capacitor C is made in the form of a shunting open loop with a reduced characteristic resistance $Z_{\text{cap}} = 1/C$ or with an actual wave resistance $Z_{\text{cap}} = R_0/C$. Similarly, the Richards inductor L is implemented as a sequential short loop with a

normalized characteristic resistance $Z_{Ind} = L$ or with an actual characteristic resistance $Z_{Ind} = R_0 L$. Thus, it turns out that $Z_{cap} = R_0/C = 50/7,5 = 6.6105$ ohms and $Z_{Ind} = R_0 L = 42.7106$ ohms. For the case under consideration, $Z_{3-act} = 6.2297$ ohms and $Z_{cap-act} = 6.6$ ohms are difficult to implement. As for practical implementation, we may prefer to use microstrip technology to implement ideal commensurate transmission lines. Richards shunt capacitors (i.e., open loops in a shunt configuration) can be easily implemented, but the implementation of Richards series inductors (i.e., short loops in a serial configuration) presents serious difficulties. However, the problems of physical implementation can be circumvented by using Kuroda identities (Abdukadyrov et al., 2023; Plotkin et al., 2021). In this regard, the sequential application of Kuroda identities removes consecutive short loops with shunting open loops (Yerzhan et al., 2023).

Identification of Kuroda 1:

According to Fig. 5, a transmission line with a capacitive load can be replaced by an equivalent line with an inductive load using the following set of equations:

$$Z_B = \frac{Z_A}{C_A Z_{A+1}}, \quad (6)$$

$$L_B = \frac{C_A Z_A^2}{C_A Z_{A+1}}, \quad (7)$$

In our case, the Richards capacitor and a pair of transmission lines $\{C\lambda, Z_4\} = \{C\lambda = 7,5637\lambda, Z_4 = 1,5364\}$ can be replaced by a pair of transmission lines and Richards inductors $\{Z_{B1}, L_{B1}\lambda\}$ so that

$$Z_{B1} = \frac{Z_A}{C_A Z_{A+1}} = 0.1217, \quad (8)$$

$$L_{B1} = \frac{C_A Z_A^2}{C_A Z_{A+1}} = 1.4146, \quad (9)$$

Thus, at the first stage, we used the Kuroda I identity and obtained the following chain topology.

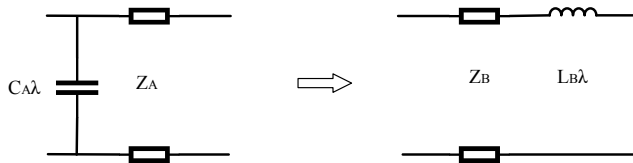


Fig. 4 - Identification of inductance using Kuroda identities

Identification of Kuroda 2

Referring to Fig. 4, the pairs $\{L\lambda, Z_{B1}\}$ and $\{L_{B1}, Z_3\}$ can be replaced by identical pairs using the Kuroda II identity, as shown in Fig. 5. The set of replacement equations is given by the expression

$$Z_B = Z_A + L_A, \quad (10)$$

$$C_B = \frac{L_A}{Z_A(Z_A + L_A)}, \quad (11)$$

In the second stage, the Kuroda II identity is applied twice. First, the pair $\{\lambda LB1, Z3\}$ is replaced by

$$Z_{B3} = Z_3 + L_{B1} = 1.5393, \quad (12)$$

or is the actual value of ZB3 equal to ZB3-act =76 ohms.

$$C_{B3} = \frac{L_{B1}}{Z_{B1}(Z_{B1} + L_{B1})} = 7.37, \quad (13)$$

Similarly, the pair $\{L\lambda, ZB1\}$ is replaced by a new $\{ZB2, CB2\}$ such that

$$Z_{B2} = Z_{B1} + L = 0.9759, \quad (14)$$

or is the actual value of ZB2 equal to ZB2-act =48.7974 ohms.

$$C_{B3} = \frac{L}{Z_{B1}(Z_{B1} + L)} = 7.1899, \quad (15)$$

Hence, we get Fig. 5 as the final synthesis of ZB2(λ)

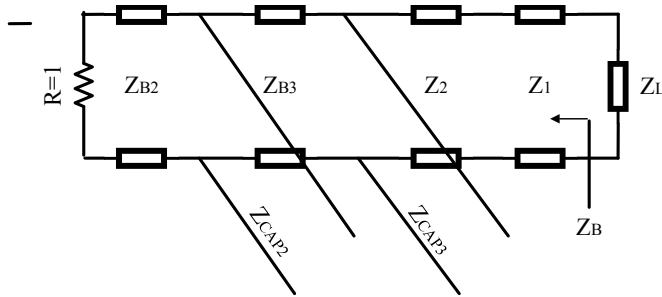


Fig.5 - Matching circuit for power amplifier LD-MOSRD07

The matching device is made on FR-4 with a dielectric constant of 4.3. The characteristics of the matched system are shown in Fig. 6.

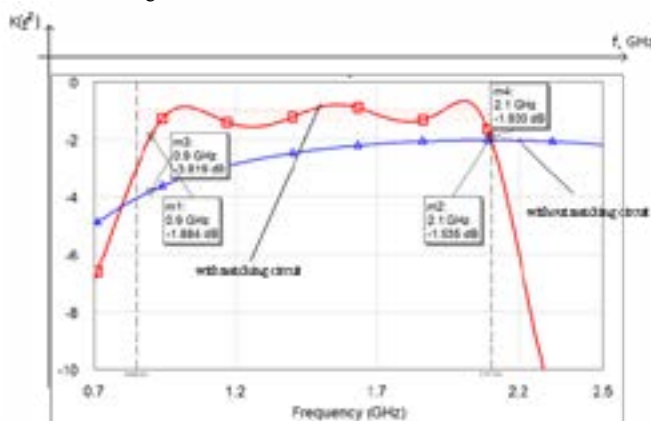


Fig. 6 - PG dependency with and without matching chain

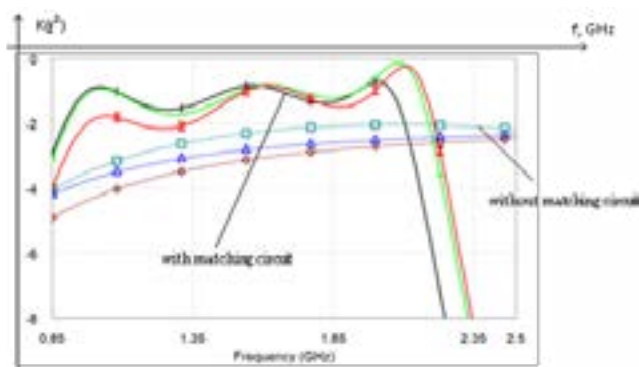


Fig. 7 - The dependence of the PG on the frequency of the amplifier with and without a matching circuit

Conclusions

In cases of instability of the amplifier parameters caused by various kinds of destabilizing factors, which led to a change in load parameters up to 25% of the nominal value, leads to a change in the PG in the bandwidth slightly when using a synthesized matching circuit (Fig. 7 – solid lines), unlike without it (Fig. 7 – dashed lines).

Based on the results obtained, it follows that the MD provides not only an improvement in PG in the frequency range from 0.9 to 2.1 GHz, but also has increased selectivity over the bandwidth. Thus, the obtained technique can be used for the synthesis of MD both in the concentrated element basis and in the microwave frequency range.

Geology is an extensive scientific concept, which includes many subsections that differ in the scope of application, category of theoretical calculations, type of research objects, described in detail below.

REFERENCES

- Alekseeva O.V., 1987 — *Alekseeva O.V. Designing radio transmitting devices using / O.V. Alekseeva // COMPUTER*. Ed. M.: Radio and Communications, 1987. – p. 392 (in Russ).
 Abdykadyrov A., Marxuly S., Kuttybayeva A., Almuratova N., Yermekbayev M., Ibekeyev S., Yerzhan

A., Bagdollauly Y., 2023 — *Abdykadyrov A., Marxuly S., Kuttybayeva A., Almuratova N., Yermekbayev M., Ibekeyev S., Yerzhan A., Bagdollauly Y.* Study of the Process of Destruction of Harmful Microorganisms in Water. *Water (Switzerland)*, 2023, 15(3), 503. <https://doi.org/10.3390/w15030503> (in Eng).

Boykachev P.V., Filippovich G.A., 2012 — *Boykachev P.V., Filippovich G.A.* Method of modification of approximating functions for the synthesis of filters and matching circuits. *Vestnik VARB № 3(36)* 2012. (in Russ).

Dubovik I.A., 2021 — *Dubovik I.A.* Methods of synthesis of matching circuits for broadband radio engineering devices with unstable load impedance / I.A. Dubovik, P.V. Boykachev, V.O. Isaev, A.A. Dmitrenko // Reports of BSUIR. 2021;19(1): Pp. 61–69. 14 (in Russ).

Dedus F.F., 2004 — *Dedus F.F.* Classical orthogonal bases in problems of analytical description and processing of information signals. / Dedus F.F.// - Moscow 2004 -11p. (in Russ).

Fano R.M., 1965 — *Fano R.M.* Theoretical limitations of the matching band of arbitrary impedances / R.M. Fano//Moscow- 1965, p. 44. (in Russ).

Filippovich G.A., 2005 — *Filippovich G.A.* Solvability of a system of constraints in broadband matching problems / G.A. Filippovich // Electromagnetic waves and electronic systems. - 2005. – Vol. 10. № 1-2. – Pp. 92–97 (in Russ).

Filippovich, G. A. — Broadband matching of resistances / G. A. Filippovich. – Minsk: VARB- 2004. – p. 175 (in Russ).

Gorshelev V.D., Krasnotsvetova Z.G., Fedortsov B.F., 1977 — *Gorshelev V.D., Krasnotsvetova Z.G., Fedortsov B.F.* Fundamentals of radio receiver design /V.D. Gorshelev//, Energia Leningrad -1977.- p. 189 (in Russ).

Moldasheva Z., Orazbayeva K., Abdugulova Z., Utenova B., Kodanova S., 2022 — *Moldasheva Z., Orazbayeva K., Abdugulova Z., Utenova B.* Method of developing models of chemical and technological systems of oil refining under uncertainty. *News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences*, (2022) 4 (454). Pp. 152–170. DOI 10.32014/2022.2518-170X.207.

Orazbayev B., Moldasheva Zh., Orazbayeva K., Makhatova V., Kurmangaziyeva L., Gabdulova A., 2021 — *Orazbayev B., Moldasheva Zh., Orazbayeva K., Makhatova V., Kurmangaziyeva L., Gabdulova A.* Development of mathematical models and optimization of operation modes of the oil heating station of main oil pipelines under conditions of fuzzy initial information. *Eastern-European Journal of Enterprise Technologies*, 6: 2(114)). Pp.147–162. DOI: <https://doi.org/10.15587/1729-4061.2021.244949>.

Plotkin J., Almuratova N., Yerzhan A., Petrushin V., 2021 — *Plotkin J., Almuratova N., Yerzhan A., Petrushin V.* Parasitic effects of pwm-vsi control leading to torque harmonics in ac drives. *Energies*, 2021, 14(6), 1713. (in Eng).

Yarman S.B., 2010 — *Yarman S.B.* Design of ultra wideband power transfer networks / S.B.Yarman .- Istanbul University, 2010.– Pp.585–602 (in Russ).

A.A. Yerzhan, P.V. Boikachev, S. Virko, Z.D. Manbetova, P.A. Dunayev, 2023 — *A.A. Yerzhan, P.V. Boikachev, S. Virko, Z.D. Manbetova, P.A. Dunayev.* A new method of matching the synthesis of matching devices based on modified approximation in telecommunication devices // NEWS of the National Academy of Sciences of the Republic of Kazakhstan, 2023, 2(458). Pp. 77–84 (in Eng).

CONTENTS

D.K. Akhmetkanov, M.Zh. Bitimbayev, V. Lozynskyi, K.B. Rysbekov, B.B. Amralinova NEW VARIANTS FOR WIDE OREBODIES HIGH-CAPACITY MINING SYSTEMS WITH CONTROLLED AND CONTINUOUS IN-LINE STOPPING.....	6
F.A. Akhundov, M. Sarbopeeve, R. Bayamirova, A. Togasheva, A. Zholbasarova ON THE ISSUE OF PREPARING THE WELLBORE FOR ITS FASTENING.....	22
A.M. Baikadamova, Y.I. Kuldeyev GEOLOGICAL STRUCTURE OF THE ZHARKENT THERMAL GROUNDWATER DEPOSIT BY THE EXAMPLE OF WELL 3-T.....	35
A.A. Yerzhan, P.V. Boikachev, B.R. Nakisbekova, Z.D. Manbetova, P.A. Dunayev METHOD OF SYNTHESIS OF MATCHING TELECOMMUNICATION DEVICES BASED ON THE METHOD OF REAL FREQUENCIES FOR 5G ANTENNAS IN A DISTRIBUTED ELEMENT BASIS.....	47
K.S. Zaurbekov, S.A. Zaurebkov, A.V. Sladkovsky, D.Y. Balgayev HYDRODYNAMIC SIMULATION OF THE STEAM-ASSISTED GRAVITY DRAINAGE METHOD FOR DIFFERENT RESERVOIR THICKNESSES USING ECLIPSE.....	60
A.T. Ibrayev, D.A. Aitimova A METHOD FOR ACCOUNTING THE IMPACT OF ERRORS ON THE QUALITY OF ANALYTICAL INSTRUMENTS AND OPTIMAL CONTROL SYSTEMS.....	70
I.G. Ikramov, G.I. Issayev, N.A. Akhmetov, SH.K. Shapalov, K.T. Abdraimova RECYCLING OF PRODUCTION WASTE AND ENVIRONMENTAL IMPACT ASSESSMENT.....	80
J.A. Ismailova, A.R. Khussainova, Luis E. Zerpa, D.N. Delikesheva, A.A. Ismailov A NEW PREDICTIVE THERMODYNAMIC MODEL OF PARAFFIN FORMATION WITH THE CALCULATION OF THE MATHEMATICAL ORIGIN OF THE POYNTING CORRECTION FACTOR.....	96
Zh.S. Kenzhetaev, K.S. Togizov, A.K. Omirgali, E.Kh. Aben, R.Zhalikyzy INTENSIFICATION OF INHIBITOR-ASSISTED URANIUM ISL PROCESS.....	108
M.A. Li, T.T. Ibrayev, N.N. Balgabayev, B.S. Kali, D.A. Toleubek SIMULATION AND OPTIMIZATION MODELING OF WATER USE MANAGEMENT IN IRRIGATION SYSTEMS.....	119
A.S. Madibekov, L.T. Ismukhanova, A.O. Zhadi, A. Mussakulkyzy, K.M. Bolatov RANKING THE TERRITORY OF THE ALMATY AGGLOMERATION ACCORDING TO THE DEGREE OF POLLUTION.....	130
E.K. Merekeyeva, K.A. Kozhakhmet, A.A. Seidaliyev CHARACTERISTICS OF THE STRUCTURAL UPLIFTS OF KURGANBAI AND BAYRAM-KYZYLADYR LOCATED WITHIN THE ZHAZGURLI DEPRESSION.....	149
R.N. Moldasheva, N.K. Shazhdekeyeva, G. Myrzagereikyzy, V.E. Makhatova, A.M. Zadagali MATHEMATICAL FOUNDATIONS OF ALGORITHMIZATION OF WATER POLLUTION MODELING PROCESSES.....	164
Y.G. Neshina, A.D. Mekhtiyev, A.D. Alkina, P.A. Dunayev, Z.D. Manbetova HARDWARE-SOFTWARE COMPLEX FOR IDENTIFICATION OF ROCK DISPLACEMENT IN PITS.....	180

M.B. Nurpeisova, Z.A. Yestemesov, V.G. Lozinsky, A.A. Ashimova, S.S. Urazova INDUSTRIAL WASTE RECYCLING – ONE OF THE KEY DIRECTIONS OF BUSINESS DEVELOPMENT.....	193
B. Orazbayev, M. Urazgaliyeva, A. Gabdulova, Zh. Moldasheva, Zh. Amanbayeva METHODS OF MULTI-CRITERIA SELECTION IN PETROLEUM GEOLOGY UNDER CONDITIONS OF FUZZY INITIAL DATA.....	206
B.R. Rakishev, A.A. Orynbay, A.B. Mussakhan AUTOMATED FORECASTING OF THE PARTICLE SIZE COMPOSITION OF BLASTED ROCKS DURING BLASTHOLE DRILLING IN HORIZONTAL UNDERGROUND WORKINGS.....	222
Y.Sh. Seithaziyev GEOCHEMICAL STUDIES OF CONDENSATE, GAS AND CORE SAMPLES DERIVED FROM GAS-CONDENSATE FIELDS IN THE MOYNKUM SAG (KAZAKHSTAN).....	242
E.Yu. Seitmuratova, R.T. Baratov, F.F. Saidasheva, V.S. Goryaeva, M.A. Mashrapova, Ya.K. Arshamov TO STUDY THE RING STRUCTURES OF CENTRAL AND SOUTHERN KAZAKHSTAN AND THEIR ORE CONTENT.....	262
J.B. Toshov, Sh.R. Malikov, O.S. Ergashev, A.K. Sherov, A. Esirkepov IMPROVING THE EFFICIENCY OF THE PROCESS OF DRILLING WELLS IN COMPLEX CONDITIONS AT GEOLOGICAL PROSPECTING SITES.....	282
V.A. Tumlert, Zh.K. Kasymbekov, R.A. Dzhaismbekova, E.V. Tumlert, B Sh. Amanbayeva INFLUENCE OF THE HYDROGEOLOGICAL MODE OF OPERATION ON THE CHARACTER OF COLLATING OF THE FILTER AND THE FILTER ZONE OF SEASONAL WELLS.....	295

Publication Ethics and Publication Malpractice in the journals of the National Academy of Sciences of the Republic of Kazakhstan

For information on Ethics in publishing and Ethical guidelines for journal publication see <http://www.elsevier.com/publishingethics> and <http://www.elsevier.com/journal-authors/ethics>.

Submission of an article to the National Academy of Sciences of the Republic of Kazakhstan implies that the described work has not been published previously (except in the form of an abstract or as part of a published lecture or academic thesis or as an electronic preprint, see <http://www.elsevier.com/postingpolicy>), that it is not under consideration for publication elsewhere, that its publication is approved by all authors and tacitly or explicitly by the responsible authorities where the work was carried out, and that, if accepted, it will not be published elsewhere in the same form, in English or in any other language, including electronically without the written consent of the copyright-holder. In particular, translations into English of papers already published in another language are not accepted.

No other forms of scientific misconduct are allowed, such as plagiarism, falsification, fraudulent data, incorrect interpretation of other works, incorrect citations, etc. The National Academy of Sciences of the Republic of Kazakhstan follows the Code of Conduct of the Committee on Publication Ethics (COPE), and follows the COPE Flowcharts for Resolving Cases of Suspected Misconduct (http://publicationethics.org/files/u2/New_Code.pdf). To verify originality, your article may be checked by the Cross Check originality detection service <http://www.elsevier.com/editors/plagdetect>.

The authors are obliged to participate in peer review process and be ready to provide corrections, clarifications, retractions and apologies when needed. All authors of a paper should have significantly contributed to the research.

The reviewers should provide objective judgments and should point out relevant published works which are not yet cited. Reviewed articles should be treated confidentially. The reviewers will be chosen in such a way that there is no conflict of interests with respect to the research, the authors and/or the research funders.

The editors have complete responsibility and authority to reject or accept a paper, and they will only accept a paper when reasonably certain. They will preserve anonymity of reviewers and promote publication of corrections, clarifications, retractions and apologies when needed. The acceptance of a paper automatically implies the copyright transfer to the National Academy of Sciences of the Republic of Kazakhstan.

The Editorial Board of the National Academy of Sciences of the Republic of Kazakhstan will monitor and safeguard publishing ethics.

Правила оформления статьи для публикации в журнале смотреть на сайтах:

www.nauka-nanrk.kz

<http://www.geolog-technical.kz/index.php/en/>

ISSN 2518-170X (Online),

ISSN 2224-5278 (Print)

Заместитель директор отдела издания научных журналов НАН РК *Р. Жәліқызы*

Редакторы: *М.С. Ахметова, Д.С. Аленов*

Верстка на компьютере *Г.Д. Жадыранова*

Подписано в печать 14.06.2023.

Формат 70х90^{1/16}. Бумага офсетная. Печать – ризограф.

20,0 п.л. Тираж 300. Заказ 3.