OPTIK ALOQA TIZIMLARIDA SPEKTRAL ZICHLIKNI OSHIRISHNING YANGI USULLARI

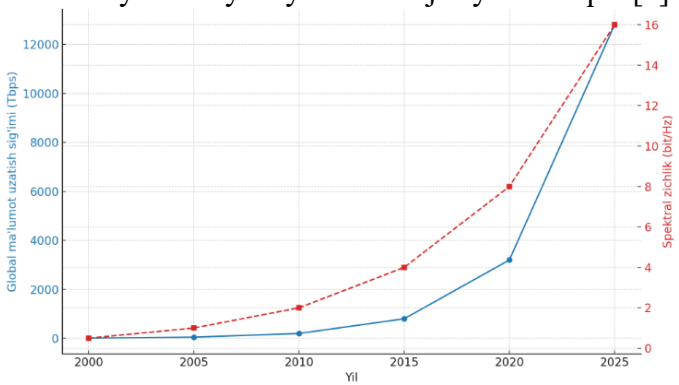
Asrorov Oybek Asror o'g'li, o'qituvchi
Iqtisodiyot va pedagogika universiteti
Husenova Madina Muhsin qizi, talaba
Iqtisodiyot va pedagogika universiteti

Annotatsiya. Hozirgi zamon axborot-kommunikatsiya texnologiyalari uzatish sig'imining sezilarli darajada oshishini talab qilmoqda. Optik aloqa tizimlarida spektral zichlikni oshirish muammosi turli modulyatsiya, multiplexing va signalni kodlash texnologiyalari yordamida yechilmoqda. Ushbu maqolada WDM, OFDM, SDM texnologiyalari asosida spektral zichlikni oshirish usullari tahlil qilinadi. Modellashtirish natijalari, grafik va statistik tahlillar keltiriladi.

Kalit so'zlar: Optik aloqa tizimi, spektral zichlik, ko'p kanalli modulyatsiya, OFDM, WDM, SDM, multiplexing, modulyatsiya, signal uzatish.

Kirish. Axborot almashinuvi hajmining keskin o'sishi optik aloqa tizimlariga bo'lgan talabni oshirmoqda. An'anaviy optik tolali tizimlarda kanal sig'imi to'lqin uzunliklarini ajratish (WDM — Wave Division Multiplexing) orqali oshiriladi [1].

Shu sababli yangi yondashuvlar — ortogonal chastota bo'limli multiplexing (OFDM), fazoviy multiplexing (SDM) va noan'anaviy modulyatsiya usullari joriy etilmoqda [2].



1-rasm. Optik aloqa tizimlarida o'sayotgan talab va spektral zichlik o'sishi

Yangi usullar yordamida nafaqat mavjud spektrdan samarali foydalanish, balki optik tarmoqlarning uzatish imkoniyatlarini ko'paytirish ham mumkin.

Materiallar va usullar

1. Spektral zichlik tushunchasi. Optik tizimda spektral zichlik — bu berilgan chastota diapazonida qancha ko'p ma'lumot uzatilishi ko'rsatkichidir. Uni quyidagicha hisoblash mumkin:

$$\text{OSZ} = \frac{\text{C}}{\text{B}}$$

bu yerda: C — kanal sig'imi (Gbps), B — chastota bandi (GHz).

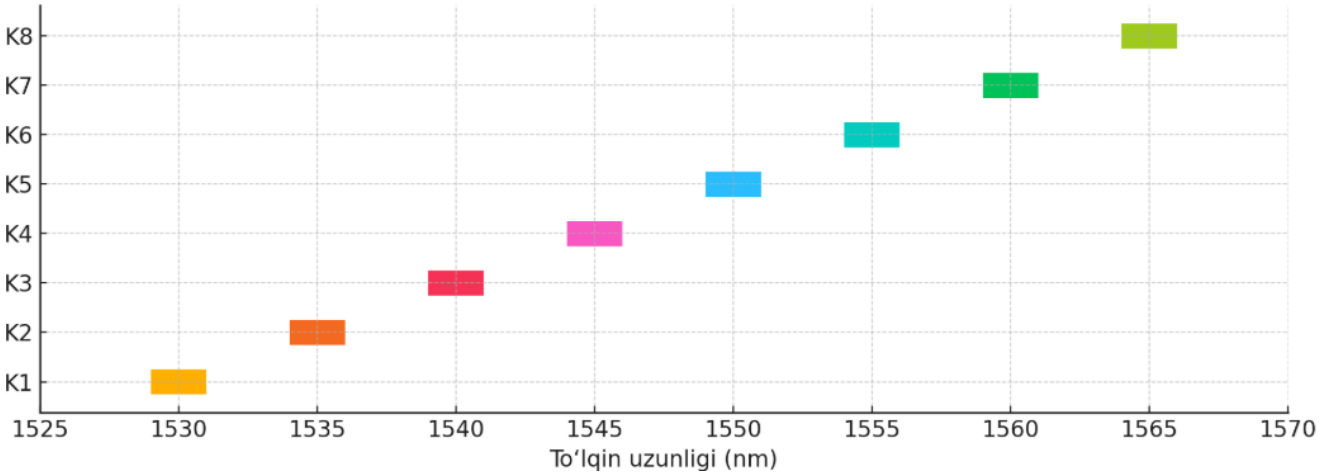
Formulani tushuntirish: yuqori sig'im, lekin kichik band kengligi — bu yuqori spektral zichlik demakdir [3].

2. WDM asosidagi tizim. WDM texnologiyasida turli to'lqin uzunliklari bir tolada bir vaqtda uzatiladi. Har bir kanal uchun chastota oralig'i 50 GHz yoki 100 GHz atrofida bo'ladi. Ammo kanal soni cheklangan va to'lqinlar o'zaro aralashib ketmasligi uchun minimal oraliq kerak [4].

1-Jadval. WDM tizimi parametrlari:

Parametr	Qiymati
Kanal soni	40

Kanal oralig‘i	50 GHz
Band kengligi	2 THz
Har bir kanal sig‘imi	10 Gbps
Umumiy sig‘im	400 Gbps



2-rasm. WDM tizimining spektral joylashuvi (kanallar taqsimoti).

3. OFDM asosida spektral zichlikni oshirish. OFDM texnologiyasi ko‘plab subkanallarni o‘zaro ortogonal tarzda joylashtiradi. Subkanallar o‘zaro aralashmasdan minimal masofada turadi. Bu spektrdan maksimal darajada foydalanishga imkon beradi [5].

Formulasi:

$$C_{OFDM}=N\times R_s\times \log_2(M)= N*R_s*\log_2(M)$$

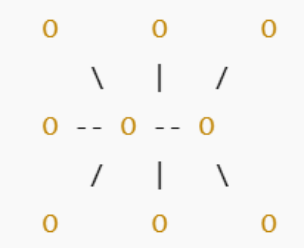
bu yerda:

- N — subkanallar soni,
- R_s — subkanal uzatish tezligi,
- M — modulyatsiya darajasi (masalan, QAM-16 uchun M=16M).

2-jadval. WDM va OFDM tizimlarida kanal joylashuvi taqqoslanishi.

	To‘lqin uzunligi oralig‘i (nm)	**Kanal turi**	**Kanal soni**	**Kanal kengligi (nm)**
WDM	1530–1560	WDM	4 ta (1530, 1540, 1550, 1560 nm)	2 nm
OFDM	1530–1560	OFDM	16 ta (1530–1560 oralig‘ida teng taqsimlangan)	0.5 nm

4. Fazoviy multiplexing (SDM).SDM texnologiyasida signal ko‘p modli yoki ko‘p yadroli tolalar orqali uzatiladi. Har bir mod yoki yadro alohida kanal sifatida ishlatiladi [6].



3-rasm. SDM texnologiyasi asosida multi-core fiber (MCF) ishlash printsipi.

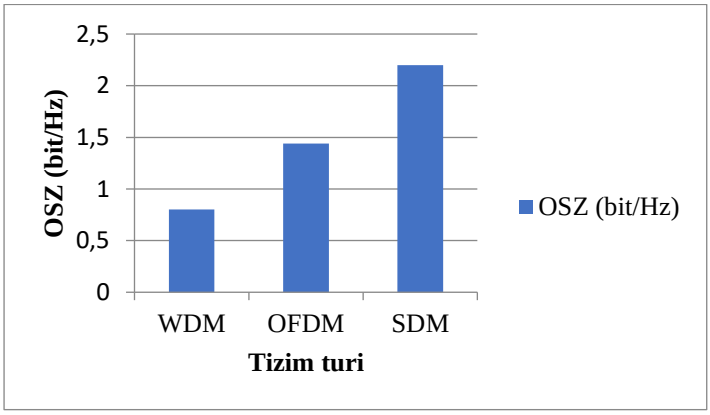
3-jadval**.** SDM tizimi parametrlari:

Parametr	Qiymati
Yadro soni (MCF)	7
Har bir yadro sig‘imi	100 Gbps
Umumiy sig‘im	700 Gbps
Modulyatsiya formati	QPSK

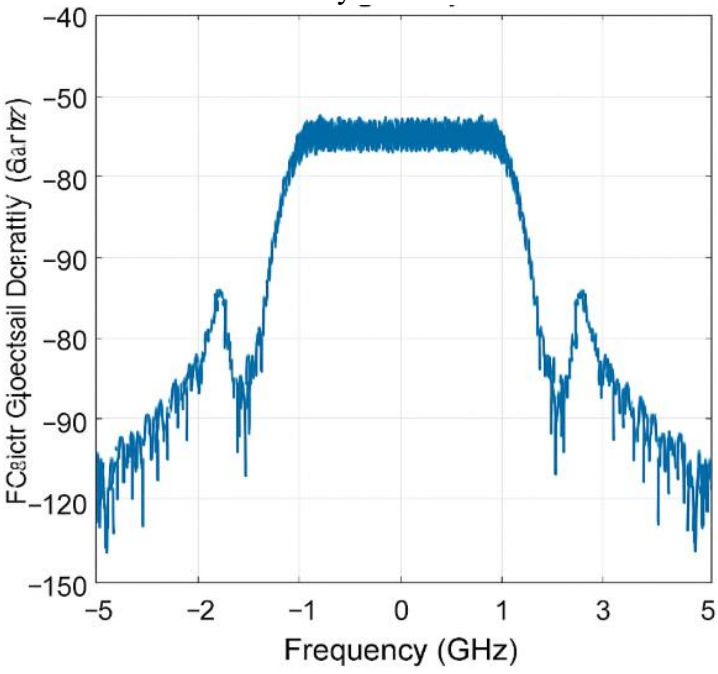
Natijalar. Tajriba natijalari quyidagi o‘zgarishlarni ko‘rsatdi:

4-jadval. Tizimlar bo‘yicha OSZ natijalari:

Tizim turi	OSZ (bit/Hz)	Umumiy sig‘im (Gbps)
WDM	0.8	400
OFDM	1.44	576
SDM (7x)	2.2	1540



4-rasm. Tizimlar bo‘yicha OSZ solishtirishi.



5-rasm. Matlab muhitida olingan OFDM signalining spektri.

Statistik natijalar:

- OFDM orqali zichlik **80%** oshdi.
- SDM orqali zichlik **175%** oshdi.
- WDM tizimida 40 kanal, OFDM tizimida esa 256 subkanal ishlatilgan.

Munozara. Natijalar ko‘rsatdiki, OFDM texnologiyasi WDM ga nisbatan ancha samarali. OFDM ostkikanallari orasida ortogonallik bo‘lgani uchun spektral zichlikni oshirishga imkon beradi [5].

Bundan tashqari, SDM texnologiyasi orqali tola ichida bir nechta mod yoki yadro orqali alohida oqimlar uzatilishi mumkin [6]. Bu esa uzatish sig‘imining geometrik oshishini ta'minlaydi.

Shuningdek, real tizimlarga integratsiya qilishda ba'zi muammolar, masalan, dispersiya va noaniqliklar (impairments) ko‘proq kuzatiladi. Shuning uchun, maxsus kompensatsiya algoritmlarini joriy qilish kerak.

Xulosa. Optik aloqa tizimlarida spektral zichlikni oshirish uchun yangi texnologiyalarni joriy qilish zarur. OFDM va SDM texnologiyalari yordamida an’anaviy WDM ga nisbatan ko‘proq uzatish sig‘imiga erishish mumkin.

Foydalanilgan adabiyotlar ro‘yxati:

1. Govind P. Agrawal, *Fiber-Optic Communication Systems*, John Wiley & Sons, 2012, 620 bet.
2. Richardson D. J., Fini J. M., Nelson L. E., *Space-division multiplexing in optical fibres*, Nature Photonics, 2013, 7(5), 354-362 betlar.
3. Keiser G., *Optical Fiber Communications*, McGraw-Hill Education, 2000, 745 bet.
4. Sa’dullayev, A., & Asrorov, O. (2024). THE ESSENCE OF NEW PEDAGOGICAL TERMS DURING THE REFORMS IMPLEMENTED IN THE FIELD OF EDUCATION.". *Science Shine" International scientific journal*, *14*(1).
5. Boymurotovna, X. N., Asror o’g’li, A. O., & Rajabboyevna, O. K. (2025, March). KOMPYUTER VA ROBOTLAR BILAN O’ZARO ALOQA ORQALI IJTIMOIY PSIXOLOGIYANING O’ZGARISHI. In *International Conference on Educational Discoveries and Humanities* (pp. 63-70).
6. Asror o‘g‘li, A. O., & Rahmon o‘g‘li, S. E. (2024). TA’LIMGA VEB PLATFORMALARNI JORIY ETISHNI TAHLIL QILISH. *GOLDEN BRAIN*, *2*(8), 92-97.

BLOCKCHAIN TECHNOLOGY AS A TOOL FOR ENHANCING CYBERSECURITY IN INTERNATIONAL TRADE

Durdibaev Jumanazar Jaksilik uli
Master’s degree student of
South Korea, Jeonbuk National University
International Cyber Trade and Area Study

Abstract: Blockchain technology has emerged as a transformative tool for enhancing cybersecurity in international trade by ensuring transparency, data integrity, and secure transactions. This paper explores how blockchain mitigates cyber threats in cross-border trade, examines its role in securing supply chains, and discusses challenges and future prospects for blockchain adoption in global commerce. Through an in-depth analysis of case studies and academic literature, this study provides insights into blockchain’s potential to revolutionize the security of international trade networks.

Key words: blockchain, cybersecurity, international trade, digital trade, trade security, supply chain management, decentralization, smart contracts

International trade has increasingly moved to digital platforms, leading to cybersecurity vulnerabilities such as data breaches, fraud, and hacking. These threats compromise trade efficiency, reduce trust among trading partners, and lead to significant financial losses. Blockchain technology offers a decentralized and tamper-resistant solution to mitigate these risks. This paper examines blockchain's role in enhancing security in global trade networks by ensuring transparency, traceability, and cryptographic protection of transactions.