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Tashkent state transport university

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The Journal of Transport showcases groundbreaking scientific and applied research conducted by transport-oriented universities, higher educational institutions, research centers, and institutes both within the Republic of Uzbekistan and globally. Recognized for its academic rigor, the journal is included in the prestigious list of scientific publications endorsed by the decree of the Presidium of the Higher Attestation Commission No. 353/3 dated April 6, 2024. This inclusion signifies its role as a vital repository for publishing primary scientific findings from doctoral dissertations, including Doctor of Philosophy (PhD) and Doctor of Science (DSc) candidates in the technical and economic sciences.

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Articles are published in Uzbek, Russian, and English, ensuring a wide-reaching audience and fostering cross-cultural academic exchange. As a beacon of academic excellence, the "Journal of Transport" continues to serve as a vital conduit for knowledge dissemination, collaboration, and innovation in the transport sector and related fields.

Study of strip elements for phased antenna arrays

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Abstract: These scientific studies using mathematical calculation software confirmed that for phased antenna arrays, the accuracy of the presented model is sufficient to understand the operating principle of antennas and approximate the radiation field. As a result of the analysis, it was found that the antenna has the best matching characteristics when the source point is located at a distance of one quarter of the length of the diagonal of the radiating element from the center of the radiator.
Keywords: wireless transmission systems, antenna, gain, radiation pattern

Fazali massiv antennalar uchun tasma elementlarini tadqiq etish

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Annotatsiya: Ushbu ilmiy tadqiqotlar, matematik hisoblash dasturidan foydalanilganda shuni tasdiqladiki, fazali massiv antennalar uchun, keltirilgan modelning aniqligi antennaning ishlash printsipini tushunish va nurlanish maydonini taxminiy hisoblash uchun etarli bo‘ldi. Tahlillar natijasida manba nuqtasi nurlatgichning markazidan nurlatgich elementi diagonali uzunligining to‘rtdan bir qismida joylashgan bo‘lsa, antenna eng yaxshi mos keladigan xususiyatlarga ega ekanligi aniqlandi.
Kalit so‘zlar: simsiz uzatish tizimlari, antenna, kuchaytirish koeffitsienti, yonalganlik diagrammasi

1. Kirish

O‘rganilayotgan antenna ekranning tepasida joylashgan to‘rtburchakli elementdir. Bunday antennadan nurlanish koaksiyal kabel liniyasini ulash orqali ta’minlanadi (1-rasmga qarang). Chiziqli polarizatsiya maydonini shakllantirish bilan nurlanish jarayonini ta’minlash uchun ma’lum bir chastota diapazonida strukturaning muvofiqlashtirilgan quvvat ta’minotini amalga oshirish kerak [1, 2, 3].

Ushbu [1-4] adabiyotlarida o’ta yuksak chastota antennalarini tuzilishlari va ishlash printsiplari va nazariyasi keltirilgan bo’lib, bularda chastota diapazoni (1850…1990) MGts diapazonlarida ishlovchi zamonaviy simsiz uzatish tizimi uchun antennalar keltirilmagan. Adabiyot [5] da elektromagnit maydon va to’lqinlarni nazariy asoslari keltirilgan bo’lib, keltirilgan adabiyotlardagi ishlardan farqli ravishda simsiz uzatish tizimi uchun zamonaviy antennalardan fazali massiv antennani matematik hisoblash dasturidan foydalanib, E va H tekisliklarida antennalarini yo‘nalish diagrammasini aniqlash hamda asosiy texnik ko’rsatgichlari bo’yich tahlilini bajarish lozim.

2. Tadqiqot metodologiyasi

Keltirilgan WCDMA uskunasida antennadan foydalanish uchun antennaning (1850…1990) MGts chastota diapazonida ishlashini ta’minlash kerak. Bunday holda diapazonning markaziy chastotasi ifoda bilan aniqlanadi

$$f_0 = \sqrt{f_{max} \cdot f_{min}}, \quad (1)$$

Bu yerda f_{max} va f_{min} - chastota diapazonining minimal va maksimal chastotalari.

Shunday qilib, berilgan diapazonning o‘rtacha to‘lqin uzunligi

$$\lambda_0 = \frac{c}{f_0} = 0{,}156 \text{ m}, \quad (2)$$

Bu yerda $c = 3 \cdot 10^8 (m/s)$ - elektromagnit tebranishlarning erkin fazoda tarqalish tezligi.

[1] ga ko‘ra, nurlatgichning kengligi nisbatdan tanlanishi kerak

$$a = \frac{0{,}5\lambda_0}{\varepsilon_1}, \quad (3)$$

Bu yerda ε_1 - havoni to‘ldirishda antennani to‘ldirishning nisbiy o‘tkazuvchanligi ε_1=1.

Nurlatgich ekrandan H masofada joylashgan. Bir tomonlama yo‘nalgan diagramma (YD) hosil qilish uchun ekranning chiziqli o‘lchami (1...3)λ dan kam bo‘lmasligi kerak. Ekrangacha bo‘lgan masofa antennani amaliy qo‘llash qulayligi (H=5 mm) va agar kerak bo‘lsa, strukturani tarmoqli elektr ta’minoti rejimini amalga oshirish imkoniyatini hisobga olgan holda tanlangan. Elektr ta’minoti tizimi 50 Om xarakterli qarshilikga ega bo‘lgan koaksiyal chiziqning bir qismi sifatida amalga oshiriladi.

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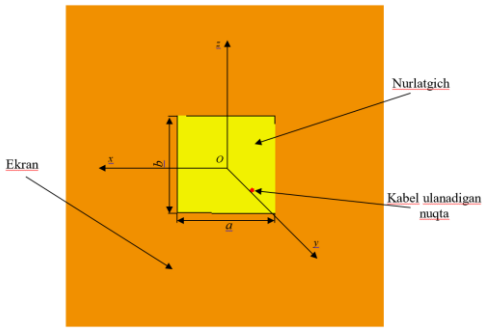
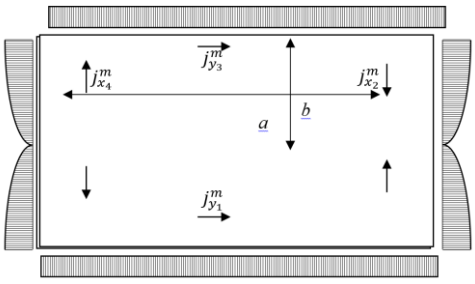
Kabelning markaziy o‘tkazgichi nurlatgich elementiga, simi ekrani esa antenna ekraniga ulangan. Ushbu ulanish oddiy va qo‘shimcha muvozanat elementlarini talab qilmaydi. Koaksiyal liniyaning ulanish nuqtasi koaksiyal kabelning ulanish joyini o‘zgartirganda antenna xususiyatlarini tahlil qilish orqali tanlangan. Dastlabki tahlillar natijasida 1-rasmda ko‘rsatilganidek, manba nuqtasi nurlatgichning markazidan nurlatgich elementi diagonali uzunligining to‘rtdan bir qismida joylashgan bo‘lsa, antenna eng yaxshi mos keladigan xususiyatlarga ega ekanligi aniqlandi.



1-rasm. To‘rtburchakli chiziqli antennaning geometriyasi

Tadqiqotning birinchi bosqichida belgilangan diapazondan biroz yuqoriroq chastota diapazonida mos keladigan rejimni ta’minlash uchun antenna o‘lchamlarini oshirish zarurligini ko‘rsatadigan antenna xarakteristikalari olindi. Natijalarni tahlil qilib, nurlatgich elementining hajmini berilgan diapazonning o‘rtacha chastotasi va mos keladigan rejim taqdim etilgan diapazonning o‘rtacha chastotasi nisbatiga mutanosib ravishda oshirishga qaror qilindi. [1] ga ko‘ra, mikropoloskali antenna dielektriksiz tekis cheksiz ekranda ekvivalent tirqishli antennasi sifatida qaraladi. Maxsus tadqiqotlar shuni tasdiqladiki, ushbu modelning aniqligi antennaning ishlash printsipini tushunish va nurlanish maydonini taxminiy hisoblash uchun etarli.



2-rasm. Mikrotirqishli antennaga ekvivalent bo‘lgan tirqish nurlatgichidagi magnit toklarning taqsimlanishi

Ekvivalent bo‘shliqning shakli metall plastinka qirralarining shakliga mos keladi deb taxmin qilinadi. 2-rasmda j_x^m va j_y^m magnit toklarining ekvivalent tirqishdagi taqsimoti ko‘rsatilgan, to‘rtburchak mikrotasmali antenna rezonatorida Ez maydonining tarqalish sxemasi asosida qurilgan.

Nurlangan maydonning hosil bo‘lishida asosiy rolni x o‘qiga parallel $\vec{E}$, vektori bilan chiziqli qutblangan nurlanish hosil qiluvchi j_{y1}^m va j_{y3}^m bir xil taqsimlangan faza ichidagi oqimlar o‘ynaydi [4, 5].

j_{x2}^m va j_{x4}^m toklari plastinkaning har ikki tomonida ikkita antifazali bo‘limni o‘z ichiga oladi, ularning nurlanishi asosan o‘zaro kompensatsiyalanadi (aniq kompensatsiya zOx va zOy tekisliklarida sodir bo‘ladi). Antennalarning nurlanish maydonlarini hisoblash usulidan foydalanib, to‘rtburchakli mikrotasma antennaning YD uchun quyidagi ifodani olishimiz mumkin:

$$f(\theta,\varphi) = \left|\cos(\vartheta)\sin(\varphi)\frac{\sin(u)}{u}\right|; \quad (4)$$

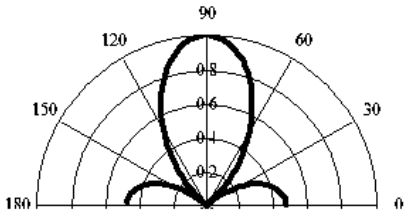
$$u = 0{,}5\beta_0 a \sin(\theta)\cos(\varphi), \vartheta = 0{,}5\beta_0 b\cos(\theta), \quad (5)$$

Bu yerda $\beta_0 = \frac{2\pi}{\lambda_0}$ - to‘lqin soni; a - element kengligi; b - element uzunligi;

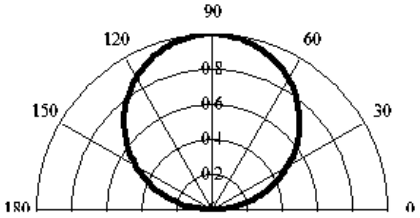
θ - balandlik tekisligida o‘lchangan kuzatuv nuqtasiga burchak yo‘nalishi;

φ - azimutal tekislikda o‘lchangan kuzatuv nuqtasiga burchak yo‘nalishi.

MathCad15 matematik hisoblash dasturidan foydalanib, E va H tekisliklarida antennalarini yo‘nalish diagrammasini (YD quramiz. E-tekisligi YD uchun YD hisoblash natijalari 3-rasmda, H-tekisligi YD uchun - 4-rasmda ko‘rsatilgan. Hisoblash f_0=1920 MGts diapazonining markaziy chastotasi uchun amalga oshirildi.



3-rasm. E-tekisligidagi to‘rtburchakli nurlatgichning YD



4-rasm. H-tekisligidagi to‘rtburchakli nurlatgichning YD

Tahlil va natijalar. Hisoblash natijalari shuni ko‘rsatadiki, -3 dB da nur kengligi E-tekisligida

40° va H-tekisligida 80°. YD shakli bir tomonlama bo‘lib, E-tekisligida yon yaproqcha nurlanishi kuzatiladi. Shuni ta’kidlash kerakki, ushbu texnik xisoblashning YD geometrik o‘lchamlari o‘zgarishiga qarab yo‘nalish xususiyatlarining o‘zgarishini aniq aniqlashga imkon bermaydi.

[2] ga ko‘ra, antennalarning yo‘nalish xususiyatlarini hisoblashda barcha antenna xarakteristikalari qatlamli strukturaning tashqi oqimlar bilan elektromagnit qo‘zg'alishi muammosini hal qilish asosida aniqlanadi. Bunday oqimlar sirt elektr bo‘lishi mumkin va plastinka yuzasi bo‘ylab oqadi. Tashqi oqimlar yordamida nurlanish xususiyatlarini hisoblash joriy usuli yordamida amalga oshirildi.

Bir qatlamli substratdagi to‘rtburchaklar uchun nurlatish maydoni quyidagi shaklga ega:

$$E(\theta,\varphi) = -\sqrt{120}[1-(\sin(\theta)\sin(\varphi))^2]^{-\frac{1}{2}} \cdot K_y[\cos(\theta)\sin^2(\varphi)\cdot G^E(\theta) + +\cos^2(\varphi)\cdot F^E(\theta)] \text{ ,(6)}$$

Bu yerda $K_y = \frac{2k_0 b}{\pi}\cdot\frac{\sin(\frac{\xi a}{2})}{\frac{\xi a}{2}}\cdot\frac{\cos(\frac{\eta b}{2})}{1-(\frac{\eta b}{2})^2}$

- Yuzaki tashqi elektr toklari uchun Furye o‘zgartirish natijasi;

$\xi = k_0\sin(\theta)\cos(\varphi)$, $\eta = k_0\sin(\theta)\sin(\varphi)$ – to‘lqin funktsiyalari;

$$G^E(\theta) = \frac{n(\theta)\cos(\theta)}{n(\theta) - i\varepsilon_1'\cos(\theta)\mathrm{ctg}[n(\theta)kd]}$$

- yordamchi funktsiya G, dielektrik ostining tuzilishini hisobga olgan holda;

$$F^E(\theta) = \frac{\cos(\theta)}{\cos(\theta) - in(\theta)\mathrm{ctg}[n(\theta)kd]}, \qquad (7)$$

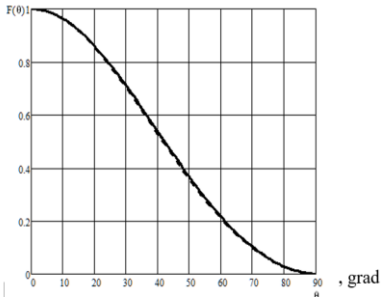
- yordamchi funktsiya F, dielektrik ostining tuzilishini hisobga olgan holda;

$$n(\theta) = \sqrt{\varepsilon_1' - \sin^2(\theta)}$$

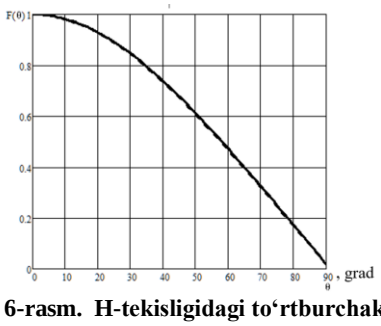
- dielektrik ostining xususiyatlarini hisobga oladigan funktsional koeffitsient.

MathCad 15 matematik hisob-kitoblar uchun dasturdan foydalanib, E va H tekisliklarida nurlanish YD ni hisoblaymiz (5 va 6-rasmlarga qarang).

Hisoblash usullarini solishtirganda shuni ta’kidlash kerakki, ikkinchi holatda dielektrik ostining xususiyatlari va tuzilishi hisobga olinadi va antennaning qutblanish samaradorligini baholash mumkin.



5-rasm. E-tekisligidagi to‘rtburchakli nurlanishning YD



6-rasm. H-tekisligidagi to‘rtburchakli nurlanishning YD

3. Xulosa

MathCad 15 matematik hisob-kitoblar uchun dasturdan foydalanib, E va H tekisliklarida nurlanish YD hisoblandi, hisoblash usullarini solishtirganda shuni ta’kidlash kerakki, ikkinchi holatda dielektrik ostining xususiyatlari va tuzilishi hisobga olinadi va antennaning qutblanish samaradorligini baholash mumkin.

Natijalarga ko‘ra, joriy usul yordamida hisoblangan asosiy yaproqcha yo‘nalish diagrammasi (YD) kengligi 60° ni tashkil qiladi, bu "rezonator" usuli yordamida hisoblangan YD kengligidan 20° kattaroqdir.

H-tekisligi uchun YD asosiy yaproqchaning kengligi "rezonator" va "joriy" usullar bilan hisoblanganda bir xil bo‘ladi.

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