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MiaHauvHOMhvH»

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MMH.MHAC[I XH X03 h MX12IAI3XUIAI 3UHa a 3HH3Ua3X3U3du XH B3X3BUaB WI3Hg0UA
33LTOQHXXH 'MHSWSda

oa KOSHinoiKHSwaH 'iaHHhHuaa 3H.MO3HH£HC[] Hogoo xcHKuaaxotj'adu aoLTXHJHO
oaxoHHmairog MEM XEX \ KHHXOHUO ojo.MoahHxawaxaw XH xaAgadx aoLTXHJHO axxogadgo
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KHHxaoaadgoadu XH iatroxsw H iauaHXHO KOXCHXHA£H nodoxox a 'HXHHXSX H HMAEH axoaugo
H axcxax oxe 'oxox 3wodj) aouaHJHO SHHaaoadgoadu oxe — 90ITBHJH3 BMxogadgo

aHHairafaduo aoxoodu aaugnaH axatf OHXCOW 'woeadgo wroiax

KHtimdocfmH Boxsaxauaen nxxogadgo waxAu xiadoxox en 'aiaHHaf xaahAuou quaxaaofaduooH 'auaHxno
KHHSKBHE uahAuou 'nwaaoua nwnjAd'f/ xiaHHau «xiqdiqo» alftia a oiAHHauaaxofaddu 'CHHHawdoc^HH
agao a XAOSH LTXHJHO :3HH3rnoHxooo aalnoiAli'auo axuaoHaxoA OHXCOW «3I3HHaU» H
«KHtimdO(J)HH» «UaHJH3» HIAIKHXKHOLI AUMOW 'WotadgO WH.MXX

7WC⁹ doiudhomo xmuuoduouo iuuooH9ifdiun9ogduouu !dtvdiuono noxoohmondgm 9 mwdirsyQ
onudHowm . 'nmoironronoo 9 iidox nomvd£ mwvgdmx dtmodhnHvxdiv tdxnwodxv 9 DHITO9
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M.Mxogadgo H Mhauadau nutf KaHtroxudu H oiMnawdocfiHM caAHH3LT3ir3duo agao a xHxcdatfoo
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HOwaatfoiugaHaH axiag auHtiHHdu a HUH aowAm woaxaahHUOx wnmairrog BuaxaotfauooH xo
axiadxo axiag xa>iow 'xiaHHaf a BOBalnaxcdali'oo 'KHHawdocJiHj^ MMHawdoc[iHM KHHOhAirou
KiTtf «wouandaxaw» wiaHiroxoH qmHir uoxoiKiraK aiaHHau 'woeadgo WM.Max

adHw ojOHauandaxaiAi aooatiodu HUH HHH3U3K 'aoxxaago axonoao xroioaMieHcf) ognu-xroiax

BHHadaweH 'HHHatfoiugaH aoxaxauAead 'aoxxacf) axooHuAxoao oxe - aiaHHBj/

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go KHH3H£ xHlnaxcdatfoo 'HHHatfaao ognu-xroiax axooHuAxoao — Bnna\ido()H||

xoiaxAu oxoan aiadoxox '«aiaHHBtf» AHMwdax axcxax a '«BHtiKwdot()HH» AHMwdax OHXBHOU axau
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axxaago ojowaAuauooH xo HiaHHaxcadxo xAae KOxauuaK WOUBHJHO auoxooxxacfiaU
OJOxoahHxoAxa KUU 'UBHJHO HiaHHOHenaauax Koxanuau WOUBHJHO adoenauax KUU 'xauAtn
OJ3 EH SHHSxcKduaH K3X3KU3K WOUBHJHO adxswxauoa KUU 'dswnduag Hxxogadgo XH H
HWXUBHJHO o iaxogad KUU iaHXKoo xoiaxogad iadogndu sag KHHSodxooodogHdu nxoaugo a

BpeMeHu $s(t)$. CaegoBaTeabHO u Bee MaTeMaTuaecKue o[^]epa[^]uu, npuMeHapo[^]ueca K OgHOMepHbIM \$yH^{ua}M\$, npHMeHHMH B peaabHHM CHpHa[^]aM, xOTa u C HeKOTOpbIMy OrOBOpKaMu.

[^]aaMu o6pa6oTKy u aHaau3a curHaaB o6waHO aBaaroTca:

- OnpegeaeHue uau o[^]HKa aucaoBbix napaMeTpOB curHaaB [^]Heprua, cpegHaa MO[^]HOCTb, cpegHee KBagpaTuaecKoe 3HaeHue u np.);
- H3yaeHue y3MeHeHua napaMeTpOB curHaaB BO BpeMeHu;
- Pa3aoc[^]eHue curHaaB Ha [^]aeMeHTapHble cocpaBaapo[^]ue gaa cpaBHeHua CBOHCTB pa3aayHwx curHaaB;
- CpaBHeHue cpeHeHy 6ayocpy, "noxo[^]ecpy", "pogcrBeHHocpy" pa3aayHwx curHaaB, B TOM auae c onpegeaeHHbIMy KoauaepBeHHbIMy o[^]HKaMu.

MaTeMaTuaecKyH annaT aHaau3a curHaaB BecbMa o6myeH, y mypoKO npuMeHaeTca Ha npaKTyKe BO Bcex 6e3 yKaapoehua o6aacrax HayKy u TexHyKy.

2. KHACCMOM[^]Mfl CMpHABOB

2.1 no pa3MepHOCTH

Pa3MepHOCTb curHaaa - [^]To aucao He3aBycMbix nepeMeHHbix, no KOTOpbIM onpegeaeTca epa 3HaeHue.

EO[^]bmyHCTBO curHaaB, pacceMpyBaeMwx B reopy, aBaaroTca OfHOMepHbIMy u yMerar Bug $s(x)$. HanpyMep, 3aBycMOCTb Hanpa[^]eHua OT BpeMeHu, aMnauTygw OT aacroTbi T.g.

Kpome Toro cy[^]ecpyeT TaK[^]e gocpaToaHO 6oabmoH Kaacc gByMepHbix curHaaB Buga $s(x,y)$. KaaccuaecKyM npuMepoM gByMepHoro curHaaa aBaeTca apoe naocKoe y3o6pa[^]eHue uau pacnpegeaeHue KaKOH-au6o BeauayHbi no reopu[^]aeKyM KOopryHaTaM.

TaK[^]e yHorga BcrpeaaroTca TpeMepHbie curHaaw, aa[^]e Bcero, Korga peab yreT o6 onpegeaeHy 3HaeHua KaKOH-au6o BeauayHbi B pa3Hwx ToaKax nocyTpaHCTBa, HanpyMep TpaKTopyy gBy[^]eHua caMoaeTa uau KocMyaekKopo Kopa6aa.

Teopya gonyKaeT cy[^]ecpOBaHue TaK[^]e MHopMepHwx curHaaB, a Kpome Toro pacmupaeT MHopue MeTogbi o6pa6oTKy Ha [^]ToT cayaH. HO B npaKTuaecKOH geaTeabhocy, TaKue cayaay BcrpeaaroTca pegKO.

2.2 no HenpewbHOCTH

Hpo6oM curHaa onpegeaeHHbie BO3MO[^]Hbie 3HaeHua Ha onpegeaeHHOM nocyTpaHCTBe 3HaeHyH He3aBycMOH nepeMeHHOH. KaK 3HaeHua, TaK y He3aBycMa nepeMeHHaa Moryt 6wTb au6o HenpewbHHMy, au6o gycKpeTHbIMy.

HenpewbHocTb — CBOHCTBO, 3aKapoapo[^]eece B nocTeneHHOM, naaBHOM, 6e3 cKaaKOB y3MeHeHy 3HaeHyH KaKOH-au6o nepeMeHHOH, \$yH^{uu} uau gpyopo MaTeMaTuaecKopo o6beKTa.

[^]HCKpeTHocTb — CBOHCTBO, nponyBonocpaaeMoe [HenpewbHocy](#), npewbHocy.

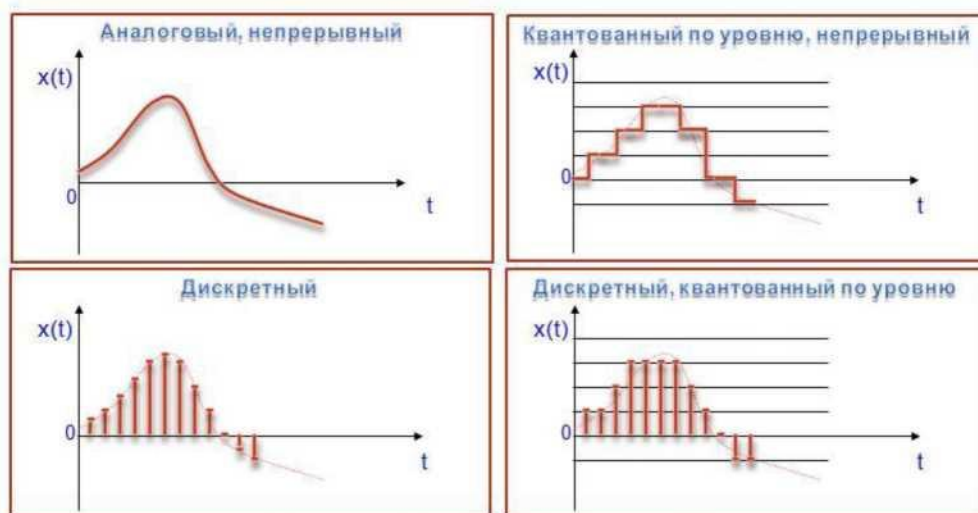
AHaopOBH (HenpeubiBHirt) cnpHaa - curHaa, 3HaeHua y He3aBycMa nepeMeHHaa KOTopopo aBaaroTca HenpewbHHMy MHO[^]ecpaMu BO3MO[^]HHX 3HaeHyH.

[^]HCKpeTHHH cnpHaa - curHaa, He3aBycMa nepeMeHHaa KOTopopo onpegeaeHa Ha gycKpeTHOM MHO[^]ecTBe, a 3HaeHua aBaaroTca HenpewbHHMy.

OTcneT curHaaa — 3HaaeHue curHaaa, B3aToe B oTgeabHwfi MOMeHT gucKpeTHoro BpeMeHu.

KBaHTOBaHHMH curHaa - curHaa, 3HaaeHua KOToporo gucKpeTHw, a He3aBucuMaa nepeMeHHaa HenepwBHa.

U,H^poBort curHaa — curHaa gaHHwx, y KoToporo Ka^gwfi u3 npegpaBapo^ux napaMeTpOB onucwBaeTca ^yH^uefi gucKpeTHoro BpeMeHu u KoHeaHWM MHO^CTBOM BO3MQSHHX 3HaaeHufi.



CooTBeTCTBeHHo, MO^HO onpegauTb caeryo^ue npegopa3oBaHua curaaaB: ^HCKpeTH3a^HH — npegec npegopa3oBaHua aHaaopoBopo curHaaa B gucKpeTHwfi. KBaHTOBaHue — npegopa3oBaHue aHaaopoBopo curHaaa B KBaHTOBaHHwfi.

Oмcl)poBKa — npegopa3oBaHue aHaaopoBopo curHaaa B gu^poBofi.

BoccpaHoBaeHue — npegopa3oBaHue curHaaa u3 gucKpeTHoro uau ^u\$poBO^o B aHaaopwfi.

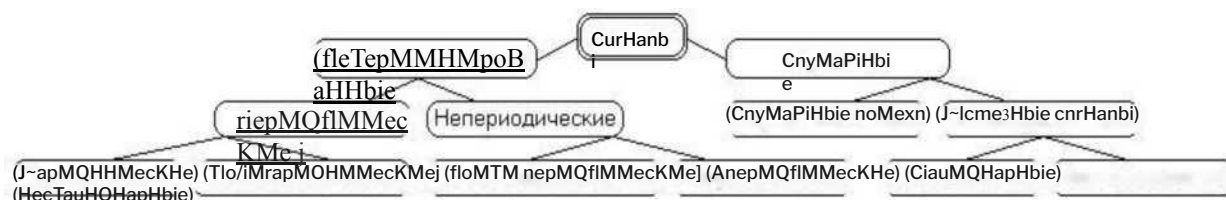
2.3 no BHgy MaTeMaTynecKofi Mogeau

nocKoabKy curHaaw nopo^aroTca \$u3ynecKuMu npo^ccaMu, a Te B CBOW onegeb MoryT yMeTb KaK caynafiHwfi, TaK u npegcKa3yeMwfi xapaKTep, curHaaw TaK^e MoryT 6wTb pa3Hopo Tyna. CooTBeTCTBeHHo oTaunapoTca u Mogeau, co3gaBaeMwe gaa KoppeKTHoro aHaau3a curHaaa.

Ecau MaTeMaTynecKaa Mogeab no3BoaeT TOHHO onpegauTb 3HaneHue curHaaa B aro6ofi TonKe, TaKaa Mogeab u TaKofi curHaa Ha3WBapoTca geTepMHHypoBaHHbiMH. HanпyMep, nпу aHaau3e Hanpa^eHua B ^aeKTrуHecKofi ceTy uMeeT cMwca ycноab3oBaTb Mogeab

$$\text{Buga } s(t) = \sin(rnt + p).$$

Ecau curHaa HOCUT caynafiHwfi xapaKTep, TO poBopaT o Haauauu caynafiHopo (cTOxacTynecKopo) curHaaa. MaTeMaTuaeKaa Mogeab B TaKoM cayaae 3agaeTca B Buge 3aKoHa pacnpegaeHua BepoATHocrefi, Koppeaa^uoHHofi \$yH^uu, cneKTPaabhofi naoTHocy ^Hep^uu u gp.



Пuc. 2. KaaccmlmKamIH curHaaOB.

2.3.1. ^eTepMHHHpoBaHHbie cнpHa^M

^eTepMHHHpoBaHHwe curHanw TaK*e gononHurenbHo Kнaccу\$u^uropyTca Ha nepyoguaeckue u Henepuoguaeckue.

K MHO^ecTBy nepHognaeckHx OTHOCAT rapMoHuaeckue u nonurapMoHuaeckue curHanw. ^na nepuoguaeckux curHanoB BbinonHaeTca o6^ee ycноBue $s(t) = s(t + kT)$, rre $k = 1, 2, 3, \dots$ - npo6oe ^noe aucно (y3 MHO^ecTaa ^nbix aucen OT -ro go ro), T - nepyog, aBнapo^yaca KoHeaHbiM oTpe3KoM He3aBcyMoa nepemeHHoa

r apMOHHeckHe cнpHa^bi (cyHcyoγanbHbie), onucwBaroTca cneyro^uMu \$opMynaMu:

$$s(t) = A \sin(2\pi f_0 t + \varphi) = A \sin(\omega_0 t + \varphi), \quad s(t) = A \cos(\omega_0 t + \varphi),$$



Рис. 3. Гармонический сигнал амплитуд

rre A , f_0 , ω_0 , φ - nocpoaHHbie BenuauHbi, KoTopwe MoryT ycnonHaTb ponb uH^opMa^uoHHHx наpаметpoB curHana: A - aMnnmyra curHana, f_0 - ^yKнuaeKaa aacpoTa B rep^x, $\omega_0 = 2\pi f_0$ - ypноBaa aacpoTa B pagaHax, φ u ^- HaaanbHbie we ypnw B pagaHax. nepyog ogHopa iaHua $T = 1/f_0 = 2\pi/\omega_0$. npy $\varphi = \omega_0 t - \pi/2$

cyHcyHwe u KocyHcyHbie \$yH^uu onucwBaroT oguH u TOT *e curHan.

no^napMOHHeckHe cнpHa^bi cocpaBнapoT Hau6oнее мupoKo pacнpocтpaHeHHyro rpyппy nepuoguaeckux curHanoB u onucwBaroTca cyMMoa rapMoHuaeckux Kone6aHua:

$$s(t) = \sum_{n=0}^N A_n \sin(2\pi f_n t + \varphi_n) = \sum_{n=0}^N A_n \sin(2\pi B_n f t + \varphi_n), \quad B_n \in \mathbb{I}, \quad (1.1.2)$$

унu HenoceгcraeHHo \$yH^uea $s(t) = y(t \pm kT_p)$, $k = 1, 2, 3, \dots$, rre T_p - nepyog ogHopa nonHopa Kone6aHua curHana $y(t)$, 3aγaHHopa Ha ogHoM nepyoge.

3HaеHue $f_p = 1/T_p$ Ha3biBaroT ^yHγaMeHTaHbHoн aacpoToa Kone6aHua.



Рис. 4. Полигармонический сигнал

nonurapMoHuaeckue curHanw npegcpaBнapoT co6oa cyMMy onpegeneHHoa nocpoaHHoa cocpaBнapo^ea ($f_0=0$) u npou3BonbHopa (B npegene - 6ecKoHeaHopa) aucна rapMoHuaeckux cocpaBнapo^ux c npou3BonbHHMu 3HaеHuaMu aMnnTyγ An u \$a3 γn, c aacpoTaMu, KpaTHHHMu ^yHγaMeHTaHbHoa aacToTe f_p . ^pyγuMu cнoBaMu, Ha nepyoge \$yHγaMeHTaHbHoa aacpoTbi f_p ,

анепуогунесКоро curHaaa, 3агаHHоро \$опMyaoM Ha uHTepBaae (0, ∞):

$$s(t) = \exp(-a \cdot t) - \exp(-b \cdot t),$$

где a и b - константы, в данном случае $a = 0.15$, $b = 0.17$.

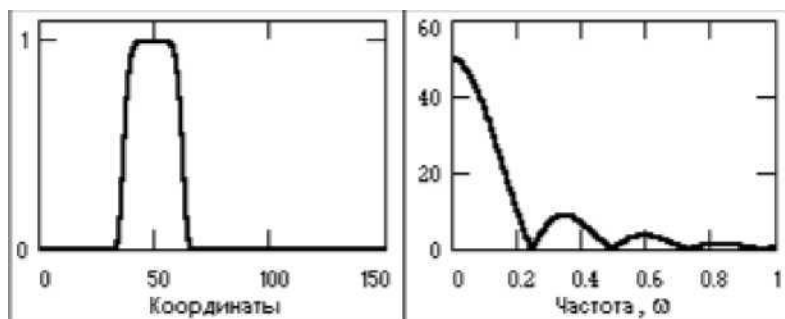


Рис. 7. Импульсный сигнал и модуль спектра

К анемпуогунесКуМ curHaaaM OTHocaTca TaK*e HMnyabCHue cнpHaabi, KOTopwe B paguoTexHUKe и B OTpacaax, мyпоKO ee ycнoab3yro^yx, наcro paccaMaTpyBaroT B Bуге OTgeabHopo Kaacca curHaaOB. HMnyabcw npegcpaBaapoT CO6OH curHaaw onpegaeHHOH и гocpaTonHO пpocpoM \$опMби, cy^ecpayro^ue B npegеaax KOHenHbix BpeMeHHbix uHTepBaaOB. CurHaa, npyBegeHHHH Ha puc. 7, OTHocypca K нycaу uMnyabcHbix.

2.4. fflyMbi H noMexH

OTgeabHyro KaTeropuro curHaaOB cocpaBaapoT myMbi и noMexH - curHaaw, ycKa^aro^ue uHTepecyro^uM curHaa. CTпopo poBopa, OHU He aBaapoTca curHaaaMu B ycxoGHOM onpegaeHyy, T.K. He HecyT HyKaKOH noae3HOH uH\$опMa^yy. Ho B TO *e BpeMa, наcro ux Ha3WBaroT curHaaaMu B TOM cMwcae, npo OHU uMepoT 3aBycyMocTb OT TOH *e He3aBycyMOH nepeMeHHOH, npo и OCHOBOHOH curHaa, и TaK*e noпo^rapoTca \$y3yнеcКуMu nпo^ccaMu. ^o^TOMy, npo6w He co3гаBaTb nyraHy^i, наcro poBopaT O «noae3HOM cнpHaae» и «myMax H noMexax».

OгHaKO cy^ecTBypoT cayna, Korga OHU MeHapoTca MecTaMu и noMexy cTaHOBaTca noae3HbiM curHaaOM. HanпyMep, npy onpegaeHyy xapakTepycpyK myMa gaa ^\$eKTUBHOH 6op6w c HUM.

noMexaMu Ha3WBaroT cToпoHHue (r.e. BHemHue no OTHomeHuro K cycreMe) BO3geMcpBua, ycKa^aro^ue noae3HWH curHaa. KaaccyнеcКуMu npyMepaMu noMex aBaapoTca ceTeBaa noMexa наcroTOH 50 ^ и ^aeKTпoMa^HUTHaa HaBogKa (noMexa), aBaapo^aaca пe3yabTaTOM BO3geMcTBua пa3aunHwx ^aeKTпoMa^HUTHwx Koaе6aHyH Ha cycreMy.

ног myMOM 3анacTyro noHyMapoT ycKa^eHua, noпo^gaeMwe caMOH cycreMOH и Hoca^ue caynaHHHH xapakTep. HanпyMep, cy^ecpayeT TenaOBOH myM пe3ycToпOB и ^ayKKep-myM TparoucpoB. fflyMw, Bcpenapo^ueca B пeaabHOH *U3HY, наCTO uMepoT cxo^ue xapakTepycTyKu, ^o^TOMy MO*HO BwgeayTb pag TunoBwx myMOB.

Cy^ecTByeT и TaKoe noHaTue, KaK ^epawe myMw. ^Tu myMw Ha3BaHw пa3aunHWMu ^eTaMu cneKTpa no aHaopyy co cBeTOM BугyMopo cneKTpa.

«EeabiM» myM - caynaHHWH curHaa, 3HaneHua KOTopopo onpegеaapoTca HopMaabHWM (raycoBcKuM) pacnpegaeHueM. nпHMep: TenaOBOH (g^OHcoBcKuM) myM

TaK*e cy^ecrayroT po30BHH, KpacHbiH (GpoyHOBCKHH, KopuaHeBbia), CUHUII, ^uoaeTOBbia, cepwM, opaH^eBHH, 3eaeHbiH u aepHbiH myMbi.

3. nAPAMETPbl CMpHAIIOB

^^HTe^bHOCTb curHaaa T onpeeraeT uHTepBaa BpeMeHu, B TeaeHue KOToporo curHaa cy^ecTByeT (oTauaeH OT Hyaa);

MaKcuMa6Hoe H MHHHMa^bHoe 3HaueHHH noKa3bnapoT guana3oH u3MeHeHua 3HaeHuM curHaaa.

^HHaMHecKHH guana3oH — aoray^M OTHomeHua HauGoabmero BO3MO*Hopo 3HaeHua KaKOH-au6o BeauauHbi K HauMeHbmeMy Bo3Mo*HoMy:

$$D = 10 \lg P_{jnx}/P_{rnm}$$

UyryHa cneKTpa curHaaa — noaoca aacTOT, B npeeraax KOTOPOH cocperoToaeHa ocHoBHaa ^Hep^ua curHaaa;

OTHomeHHe curHaa/myM paBH oTHomeHpo MO^HOCTY noae3Hopo curHaaa K MO^HOCTY myMa;

HacTOTa gncKpeTH3a^in gucKpeTHopo curHaaa — aacroTa caegoBaHua oTcaeToB.

nepyog fHCKpeTH3a^HH — paccToaHue Me*gy gByMa cocerHuMu oTcaeTaMu. TeKy^ee cpegHee 3HaeHue 3a onpeeraeHHoe BpeMn:

$$(l/T) 6, ' *^T s(t) dt.$$

nocTOHHHaa cocTaBapoe^an:

$$(l/T) 6o^T s(') dt.$$

CpegHee BunpHMaeeHHoe 3HaeHue:

$$(l/T) 6o^T |s(t)| dt.$$

CpegHee KBagpaTHHHoe 3HaeHue:

$$.1 6 o^T x(t)^2 dt " T .$$

3.1. ^Hep^eTHecKHe napaMeTp

B Teopy curHaaB mupoKo ucnoab3yroTca ^Hep^eTuaeckue xapaKrepucTuKu. nycTb curHaa npegpaBaeT u3MeHeHue Hanpa^eHua $U(t)$ uau ToKa $i(t)$. Torga Ha pe3ycrop e conpoTyBaeHueM R BbigeaeTca MrHoBeHHaa (reKy^aa) Mo^HocTb

$$p(t) = ^P- = Ri^2(t)$$

A

Ecau MrHOBBeHHaa MO[^]HocTb curHaaa ucnoab3yeTca gaa cpaBHeHua pa3auuHbix curHaaOB, TO MO*HO npuHaTb $R = 1$ OM («HopMupoBaTb» MO[^]HOCTb). Torga Bbipa^eHua gaa MrHOBBeHHOU MO[^]HOCTu UMCWT OguHaKOBbIU Bug. [^]O[^]TOMy B Teopuu CUpHa[^]OB npu HaTO onpeeraTb MrHOBBeHHy MO[^]HocTb caeryro[^]uM o6pa3OM:

$$p_i(t) = x(t)$$

[^]Hep[^]ua u cpegHaa MO[^]HocTb curHaaa, 3aiaHHoro Ha uHTepBaae $[t_1, t_2]$, cooTBeTCTBeHHO

onpeeraoTca Bbipa^eHuaMu:

$$E = \int_{t_1}^{t_2} p(t) dt = \int_{t_1}^{t_2} x^2(t) dt$$

$$P_{cp} = \frac{1}{t_2 - t_1} \int_{t_1}^{t_2} x^2(t) dt$$

Ecau curHaa onpeeraeH Ha uHTepBaae $0 < t < T$, TO cpegHaa MO[^]HocTb

$$P_{cp} = \lim_{T \rightarrow \infty} \frac{1}{T} \int_0^T x^2(t) dt$$

HMTEPATbIA

1. [^]aBbigoB A.B. He[^]uu no Teopuu curHaaOB u [^]OC <http://prodav.narod.ru/>
2. BagyTOB O.C. <http://portal.tpu.ru/SHARED/v/VOS>
3. A. OnneHreuM [^]u\$poBaa o6pa6oTKa curHaaOB
4. CeprueHKO A.E. [^]\$poBaa o6pa6oTKa curHaaOB
5. [^]baKOHOB B., A6paMeHKOBa H. MATLAB o6pa6oTKa curHaaOB u y3o6pa^eHuu
6. MKYO CaTO O6pa6oTKa curHaaOB. nepBoe 3HaKOMCTBO
7. EacKaKOB C.H. PaguoTexHuuecKue curHaaw u [^]nu
8. poHopocKuu H.C. PaguoTexHuuecKue curHaaw u [^]nu