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KARAKTERISTIKE SLOŽENIH KOMBINERA U DVA TRENUTKA VREMENA U PRISUSTVU FEDINGA

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CHARACTERISTICS OF COMPLEX COMBINERS AT TWO TIME INSTANTS IN THE PRESENCE OF FADING

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Podaci o mentoru i članovima komisije

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Naslov doktorske disertacije:

Karakteristike složenih kombinera u dva trenutka vremena u prisustvu fedinga

Rezime:

U ovoj disertaciji se razmatraju performanse bežičnih telekomunikacionih sistema u prisustvu šuma, smetnji i fedinga kada se semplovanje vrši u dva trenutka vremena. Cilj upotrebe ovakve metode je poboljšanje pouzdanosti i povećanje kapaciteta bez povećanja snage prenosa i prenosnog opsega, u odnosu na klasične kombinere kada se semplovanje vrši u jednom trenutku vremena.

Tokom prenosa digitalno modulisanih signala kroz komunikacione kanale dolazi do fluktuacija amplitude prijemnog signala u tokom kratkotrajnih vremenskih intervala. Ova pojava se naziva feding. Ukupan feding u sistemu je kompleksna kombinacija fedinga usled interferencije između dve ili više komponenti signala koje se prostiru po različitim putanjama i efekta senke. Efikasna i pritom isplativa tehnika za prevazilaženje fedinga i poboljšanje performansi jeste diverziti prenos. Ova tehnika se zasniva na slučajnoj prirodi prostiranja signala, tako što se za dobijanje korisnog signala koriste signali dobijeni iz različitih grana prijemnika. Ukoliko signal na jednoj putanji oslabi, u određenom trenutku na drugoj putanji on može biti jači, pa se zbog postojanja većeg broja putanja mogu značajno poboljšati performanse sistema. U ovom radu će biti predstavljena kombinacija prostornog diverzita i semplovanja signala u dva vremenska trenutka.

Kombinovanje sa selekcijom (SC) i kombinovanje sa prebacivanjem (SSC) predstavljaju jednostavne i široko korišćene tehnike, gde se za razliku od kombinovanja sa maksimalnim odnosom (MRC) i kombinovanja sa istom težinom (EGC), procesira samo jedna grana prijemnika. Kada se koristi SC tehnika kombinovanja, signal na izlazu jednak je najboljoj vrednosti signala na ulazu u kombiner. U slučaju SSC kombinera sa dve grane, najpre se ispituje jedna grana i ona ostaje selektovana sve dok je vrednost signala ili odnosa signal-šum veća od unapred definisanog praga. Kada je vrednost signala prve grane manja od praga odlučivanja, kombiner prelazi na drugu granu.

U disertaciji se razmatra SSC kombiner sa dva ulaza u dva vremenska trenutka. Verovatnoća događaja da kombiner prvo ispituje signal na nekom od ulaza je ista kao kod SSC kombinera u kome se razmatra jedan vremenski trenutak, i ona zavisi od funkcija raspodele verovatnoće za vrednost praga odlučivanja u ulaznim kanalima SSC kombinera. Pretpostavlja se da signali nisu korelisani između grana prijemnika, što je veoma čest slučaj u mobilnim komunikacijama, a da postoji korelacija između signala u jednoj grani u dva vremenska trenutka. Na osnovu odlučivanja SSC kombinera u dva trenutka vremena dobijeni su izrazi za združenu gustinu raspodele verovatnoće signala na izlazu SSC kombinera u dva trenutka vremena za Rayleigh-jev, Nakagami-m, Rice-ov, Weibull-ov, log-normalni i gamma feding, na osnovu kojih će se mogu dobiti parametri koji karakterišu performanse složenog SSC/SC kombinera.

Gustine raspodele verovatnoće izvoda signala na izlazima iz SSC kombinera u dva trenutka vremena biće definisane za različite tipove fedinga. Za Rayleigh-jev, Nakagami-m, Rice-ov i log-normalni feding, izvodi signala imaju normalnu raspodelu sa nultom srednjom vrednošću i nekorelisani su kako međusobno u dva vremenska trenutka, tako i sa samim signalom. Za Weibull-ovu i gamma raspodelu izvodi signala takođe imaju normalnu raspodelu, ali varijansa izvoda zavisi od vrednosti signala, što je pokazano u literaturi. I u ovom slučaju se može uzeti da su izvodi signala međusobno nekorelisani.

Performanse složenog SSC/SC prijemnika u dva trenutka vremena se mogu dobiti kada signali na izlazu iz SSC kombinera predstavljaju ulaze u SC kombiner. Za Rayleigh-jev, Nakagami-m, Rice-ov, Weibull-ov, log-normalni i gamma feding se dobijaju izrazi za gustinu raspodele verovatnoće i verovatnoću otkaza na izlazu iz složenog SSC/SC kombinera. Verovatnoća otkaza i srednja verovatnoća greške po bitu ili simbolu su najčešće korišćeni parametri za merenje performansi SSC i SC diverziti sistema. Ipak u određenim telekomunikacionim bežičnim sistemima ovi parametri ne obezbeđuju dovoljno informacija za projektovanje i konfigurisanje sistema, pa se koriste i parametri drugog reda kao što su

srednja učestanost preseka nivoa i srednje trajanje otkaza. Ovo naročito važi za proračun brzine prenosa po simbolu, dužinu paketa i trajanje vremenskog slota. U ovoj disertaciji će biti predstavljene karakteristike drugog reda SSC/SC prijemnika. Na osnovu izraza za gustine raspodele verovatnoće izvoda signala na izlazima iz SSC kombinera u dva trenutka vremena i izraza za združenu gustinu raspodele verovatnoće signala na izlazu, biće dobijene vrednosti za srednju učestanost preseka nivoa. Takođe će upotrebom srednje učestanosti preseka nivoa i verovatnoće otkaza biti izveden izraz za srednje trajanje otkaza.

Predložena tema je aktuelna sa naučnog stanovišta, jer sa razvojem mobilne telefonije i bežičnih telekomunikacija, primena ovih sistema u prenosu telekomunikacionih signala postaje sve zastupljenija. Rezultati izloženi u ovoj disertaciji mogu imati i praktičnu primenu.

Ključne reči:
Feding, kombinovanje, gustina raspodele verovatnoće, karakteristike drugog reda, verovatnoća otkaza, SSC kombiner, SC kombiner.

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Characteristics of complex combiners at two time instants in the presence of fading

Abstract:

Performances of wireless telecommunications systems in the presence of noise, interference and fading when the sampling is done at two time instants are discussed in this dissertation. The goal of using this method is to improve reliability and increase capacity without increasing the transmission power and transmission bandwidth, compared to conventional combiner when sampling is done at one time instant.

During the transmission of digitally modulated signals through communication channels some fluctuations in the amplitude of the received signal during short time intervals may occur. This phenomenon is called fading. Total fading in the system is defined as a complex combination of fading due to interference between two or more components of the signal arriving from different paths and shadowing. Efficient and at the same time cost-effective technique for reduce of fading and performance improvement are the diversity combining technique. This technique is based on the random nature of the signal propagation, since the useful signal is obtained using signals obtained from different branches of the receiver. If the signal on one path is attenuated, at some specific moment the same signal that goes through a different path can be stronger. In this way the existence of a more than one path can

significantly improve system performances. In this study, the combination of the spatial diversity and sampling signals at two time points will be presented.

Selection combining (SC) and switch and stay combining (SSC) represent simple and widely used techniques process only one branch of the receiver, opposed to maximum ratio combining (MRC) and equal gain combining (EGC) that use all the received signals. When using the SC combining technique, the signal at the output is equal to the highest value of the combiner's input signal. In the case of the SSC combiner with two branches, one branch is selected, and it remains selected until the value of the signal or the signal to noise ratio stays greater than a predefined threshold. When the signal value of the first branch is less than the threshold, the combiner switches to another branch.

In this dissertation the SSC combiner with two inputs at two time instants is discussed. The probability of events that combiner first analyse the signal from one of the inputs is the same as for SSC combiner which considers one time instant, and it depends on the probability distribution functions for the given threshold value at the input channels of the SSC combiner. It is assumed that the signals are not correlated between the branches of the receiver, which is the common case in mobile communications, and that there is a correlation between the signals in one branch at the two different time instants. According to the SSC combiner decision-making at two time instants, the expressions for the joint probability density functions of the signals at the output of the SSC combiner at two time instants for Rayleigh's, Nakagami-m, Rice's, Weibull, log-normal and gamma fading are obtained. In this way, one can obtain parameters that characterize the performance of a complex SSC/SC combiner.

Probability density functions for the signal derivatives at the SSC combiner output at two time instances will be defined for several different fading types. For Rayleigh's, Nakagami-m, Rice's and log-normal fading, signal derivatives have normal distribution with zero mean, and they are mutually uncorrelated at two time instants, as well as with the signal itself. For Weibull and gamma distribution signal derivatives also have a normal distribution, while the variance of the derivative depends on the value of the signal, as shown in the literature. In this case it could be assumed that the signal derivatives are mutually uncorrelated.

Performances of complex SSC/SC receiver at two time instants can be obtained when the signals at the output of the SSC combiner are used as the inputs of the SC combiner. For Rayleigh's, Nakagami-m, Rice's, Weibull, log-normal and gamma fading, one can obtain expressions for probability density function and outage probability at the output of the complex SSC/SC combiner. Outage probability and the average bit or symbol error rate are

the most commonly used parameters for performance measures of the SSC and SC diversity system. However, in certain telecommunication wireless systems, these parameters do not provide sufficient information for the design and configuration of the system, and the second order statistics parameters are used instead, such as level crossing rate and average fade duration. This is particularly important for the calculation of the transfer speed per symbol, the length of the packet and the duration of the time slots. In this dissertation, it will be presented the second order statistics of SSC/SC receiver. Using the expressions for joint probability density function for the signal and the signal derivative at the output of the SSC combiner at two time instants, the expression for level crossing rate will be obtained. The average fade duration can be obtained using the level crossing rate and the outage probability.

The subject of this dissertation is a very topical from a scientific point of view, because with the development of mobile and wireless telecommunications, the use of these systems in the transmission of telecommunications signals significantly increases. Results presented in this thesis can have many practical applications.

Keywords:
Fading, combining, probability density function, second order characteristics, outage probability, SSC combiner, SC combiner.

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Sadržaj

Spisak slika

1 Uvod

U ovoj disertaciji se razmatraju performanse bežičnih telekomunikacionih sistema u prisustvu šuma, smetnji i fedinga kada se odmeravanje vrši u dva trenutka vremena. Cilj upotrebe ovakve metode je poboljšanje pouzdanosti i povećanje kapaciteta bez povećanja snage prenosa i prenosnog opsega, u odnosu na klasične kombinere kada se odmeravanje vrši u jednom trenutku vremena.

Tokom prenosa digitalno modulisanih signala kroz komunikacione kanale dolazi do fluktuacija amplitude prijemnog signala u toku kratkog vremenskog intervala. Ova pojava se naziva feding [1]-[3]. Ukupan feding u sistemu je kompleksna kombinacija fedinga usled interferencije između dve ili više komponenti signala koje se prostiru po različitim putanjama i efekta senke. Feding koji nastaje zbog prostiranja duž više putanja je relativno brz i odgovoran je za kratke varijacije signala, dok usled efekta senke dolazi do sporijih varijacija nivoa srednje vrednosti signala. Efikasna i pritom isplativa tehnika za prevazilaženje fedinga, i samim tim poboljšanje performansi, predstavlja diverziti prenos [1], [4]. Ova tehnika se zasniva na slučajnoj prirodi prostiranja signala, tako što se za dobijanje korisnog signala koriste signali dobijeni iz različitih grana prijemnika. Ukoliko signal na jednoj putanji oslabi, u određenom trenutku na drugoj putanji on može biti jači, pa se zbog postojanja većeg broja putanja mogu značajno poboljšati performanse sistema. Postoje vremenski, prostorni i frekventni diverziti. U mobilnim telekomunikacionim sistema se najčešće koriste prostorni diverziti. Vrše se razne vrste kombinovanja signala koji se pojavljuju na ulazu u diverziti sistem. Kombinovanje može biti predetekciono i posledetekciono. U ovom radu će biti predstavljena kombinacija prostornog diverzita i odmeravanja signala u dva vremenska trenutka.

U radu će detaljno biti razmatran uticaj brzog fedinga nastao zbog prostiranja signala po više puteva i sporog efekta senke na performanse sistema. Amplituda signala na ulazu u prijemnik ima Rayleigh-jevu gustinu raspodele verovatnoće ako postoji više komponenti signala sa približno konstantnim amplitudama i sa uniformno raspodeljenim fazama [5]. Do Rice-ovog fedinga dolazi kada se na prijemu pojavljuje dominatna komponenta koja je najčešće direktni talas [6]. U urbanim sredinama, zbog složenih refleksija sistema, amplituda signala ima Nakagami-m gustinu verovatnoće [1]. Weibull-ovom raspodelom se može predstaviti amplituda fedinga usled prostiranja signala po više putanja, naročito za mobilne telekomunikacione sisteme koji rade u frekventnom opsegu 800/900 MHz [7],[8]. Osim brzog fedinga, pri prostiranju signala može doći i do pojave efekta senke, kada su promene amplitude signala spore. U ovom slučaju amplituda signala ima log-normalnu raspodelu [9], [10]. Gamma raspodela se može koristiti za modelovanje efekta senke umesto log-normalne, zbog lakšeg matematičkog određivanja karakteristika sistema, naročito kod složenih raspodela fedinga, gde istovremeno deluju i brzi feding i efekat senke [11].

Kombinovanje sa selekcijom (selection combining - SC) i kombinovanje sa prebacivanjem (switch and stay - SSC) predstavljaju jednostavne i široko korišćene tehnike, gde se za razliku od kombinovanja sa maksimalnim odnosom (maximal ratio combining - MRC) i kombinovanja sa istom težinom (equal gain combining - EGC), procesira samo jedna grana prijemnika [1].

Kada se koristi SC tehnika kombinovanja, signal na izlazu jednak je najboljoj vrednosti signala na ulazu u kombiner. Sagias i ostali su analizirali karakteristike SC prijemnika sa dve grane u prisustvu nekorelisanih Weibull feding kanala sa različitim parametrima raspodele u [12], a u prisustvu korelisanih kanala u [13]. Dobili su u zatvorenom obliku izraze za gustinu raspodele verovatnoće, verovatnoću otkaza i momente odnosa signal-šum.

U slučaju SSC kombinera sa dve grane, kombiner prvo ispituje jednu granu i ona ostaje selektovana sve dok je vrednost signala ili odnosa signal-šum na njoj veća od unapred definisanog praga, čak i kada je vrednost signala, tj. odnosa signal-šum, na drugoj grani veća od vrednosti na prvoj [1], [14]. Kada je vrednost signala na prvoj grani manja od praga odlučivanja, kombiner prelazi na drugu granu, i ostaje na njoj sve dok vrednost ulaznog signala ne padne ispod praga.

Verovatnoća otkaza i srednja verovatnoća greške po bitu ili simbolu su najčešće korišćeni parametri za merenje performansi SSC i SC diverziti sistema. Ipak, u određenim bežičnim telekomunikacionim sistemima, kao što su adaptivni i kodirani prenosni sistemi, ovi parametri ne obezbeđuju dovoljno informacija za projektovanje i konfigurisanje sistema. U tom slučaju se koriste i parametri drugog reda kao što su srednja učestanost preseka nivoa i srednje trajanje otkaza, naročito za proračun brzine prenosa po simbolu, dužine paketa i trajanje vremenskog slota.

Gustine raspodele verovatnoće izvoda signala na izlazima iz SSC kombinera u dva trenutka vremena će takođe biti definisane. Na sličan način kao i za signale biće razmatrane različite raspodele fedinga.

Za Rayleigh-jev, Nakagami-m, Rice-ov i log-normalni feding, izvodi signala imaju normalnu raspodelu sa nultom srednjom vrednošću i nekorelisani su kako međusobno u dva vremenska trenutka, tako i sa samim signalom [15],[16]. Varijansa izvoda za ove raspodele zavisi od varijanse signala i od maksimalne Doppler-ove frekvencije. Za Weibull-ovu [17], i gamma raspodelu [18],[19] izvodi signala takođe imaju normalnu raspodelu, ali varijansa izvoda zavisi od vrednosti signala. I u ovom slučaju se može smatrati da su izvodi signala međusobno nekorelisani.

Karakteristike drugog reda za SC kombiner su analizirali Yang i Alouni u [18] i dali analitički metod za procenu srednjeg broja osnih preseka (level crossing rate - LCR) i srednje trajanje otkaza (average outage duration - AOD) za generalizovani SC kombiner sa nezavisnim kanalima, koji ne moraju da imaju identične raspodele, a zatim je data detaljnija analiza za nezavisne feding kanale sa identičnom Rayleigh-jevom rapodelom. U [20] Chakrabotry i Yong dobijaju LCR i AOD za SC kombiner u prisustvu nekorelisanog i identičnog Rayleigh-jevog fedinga na ulaznim granama.

Mitić i Stefanović su u [21] dobili LCR i AOD za prenosni SC prijemnik u prisustvu složenog fedinga koji se sastoji od Rice-ovog fedinga i efekta senke, za nezavisne grane sa istim parametrima feding kanala.

Yang i Alouni su u [15] dobili izraze u zatvorenom obliku za LCR i AOD za SSC kombinere. Rezultati su prilično opšti i primenljivi na sisteme sa dve grane sa istim ili različitim pragovima, sa nezavisnim feding kanalima koji ne moraju da imaju identične raspodele. Upoređeni su LCR i AOD za SSC i SC kombinere i pokazano je da za odgovarajući izbor praga odluke, SSC obezbeđuje manji AOD od SC, ali sa većim LCR, odnosno frekvencijom otkaza. U radovima autora disertacije sa kolegama analizirane su karakteristike drugog reda SSC kombinera za različite tipove fedinga [22]-[28].

Složeni kombineri u dva trenutka vremena nisu mnogo razmatrani u dostupnoj literaturi, osim u radovima grupe autora među kojima je i autor disertacije. U radovima [29]-[31] su analizirane karakteristike SSC kombinera u dva trenutka vremena i dobijeni izrazi za združene gustine raspodele verovatnoće na izlazu iz kombinera u dva trenutka vremena. Parametri prvog reda SSC/SC kombinera su dati u radovima [32], [33], dok su u [34]-[39] određene karakteristike prvog reda (verovatnoća otkaza i verovatnoća greške po bitu) za SSC/MRC kombiner u dva trenutka vremena. Karakteristike drugog reda za SSC kombiner u dva trenutka vremena su predstavljene u radovima [40]-[42], a za složeni SSC/SC kombiner u prisustvu Rice-ovog fedinga u [43].

U drugoj glavi ove doktorske disertacije biće dat kratak prikaz osnovnih karakteristika i parametara bežičnih digitalnih prenosnih sistema u prisustvu fedinga. U poglavlju 2.1. biće predstavljeni osnovni parametri feding kanala, kao i njihova klasifikacija. U narednom poglavlju će biti prikazane statističke veličine kojima se opisuju karakteristike bežičnih prenosnih sistema u prisustvu fedinga. U poglavlju 2.3. će biti izložen sažeti prikaz diverziti tehnika za poboljšanje karakteristika bežičnih telekomunikacionih sistema u kanalima sa fedingom, dok će različiti osnovni i hibridni tipovi diverziti sistema biti opisani u poglavlju 2.4. Odmeravanje signala u digitalnim bežinim telekomunikacionim sistemima će ukratko biti prikazano u poglavlju 2.5.

U trećoj glavi disertacije razmatra se SSC kombiner sa dva ulaza i sa odmeravanjem u dva vremenska trenutka. Verovatnoće događaja da kombiner prvo ispituje signal na prvom i na drugom ulazu su iste kao za SSC kombiner sa odmeravanjem u jednom vremenskom trenutku i zavise od funkcija raspodele verovatnoće za vrednost praga odlučivanja u ulaznim kanalima SSC kombinera. Pretpostavlja se da signali nisu korelisani između grana prijemnika, što je veoma čest slučaj u mobilnim komunikacijama, a da postoji korelacija između signala u jednoj grani u dva vremenska trenutka. Zavisno od vrednosti signala na ulazima u SSC kombiner u dva trenutka vremena moguća su četiri slučaja. Ako kombiner prvo ispituje signal na prvom ulazu u prvom trenutku vremena i vrednost signala je iznad praga, SSC kombiner propušta signal sa prvog ulaza za prvi vremenski trenutak u kolo za odlučivanje i razmatra vrednost signala na prvoj grani u drugom vremenskom trenutku. Ako je vrednost signala na prvom ulazu iznad praga, onda se i u drugom trenuktu bira signal sa prve grane, a ako je ispod praga, SSC kombiner u drugom trenutku vremena propušta signal sa drugog ulaza u kolo za odlučivanje, bez obzira da li njegova vrednost iznad ili ispod praga. Ako je vrednost signala na prvom ulazu u prvom trenutku vremena ispod praga, onda na kolo za odlučivanje ide signal sa drugog ulaza, koji se prvo ispituje i u drugom trenutku vremena. Ako je i tada iznad praga, SSC kombiner u drugom trenutku vremena propušta signal sa drugog ulaza a ako je ispod praga u kolo za odlučivanje ide signal sa prvog ulaza. Ako SSC kombiner prvo ispituje signal sa druge grane, logika odlučivanja je ekvivalentna slučaju kada se prvo ispituje prvi signal. Na osnovu odlučivanja SSC kombinera u dva trenutka vremena će biti dobijeni izrazi za združenu gustinu raspodele verovatnoće signala na izlazu SSC kombinera u dva trenutka vremena za Rayleigh-jev, Nakagami-m, Rice-ov, Weibull-ov, log-normalni i gamma feding, na osnovu kojih će se dobiti parametri koji karakterišu performanse složenog SSC/SC kombinera.

Četvrta glava je posvećena dobijanju karakteristika drugog reda SSC kombinera u dva trenutka vremena. Biće dobijeni izrazi za združene gustine raspodele verovatnoće signala i njihovih izvoda na izlazu iz kombinera u dva vremenska trenutka i za gustine raspodele verovatnoće izvoda signala za raspodele kod kojih signal i izvod nisu korelisani. Rezultati će biti dobijeni pod pretpostravkom da su signali u prvom i drugom vremenskom trenutku u jednoj grani kombinera međusobno nekorelisani. Na osnovu opštih izraza će biti analiziran sistem u prisustvu Rayleigh-jevog, Nakagami-m, Rice-ovog, log-normalnog i Weibull-ovog fedinga.

U petoj glavi će biti dobijeni parametri složenog SSC/SC prijemnika u dva trenutka vremena, kada signali na izlazu iz SSC kombinera razmatranog u trećoj glavi predstavljaju ulaze u SC kombiner. Za Rayleigh-jev i log-normalni feding koji predstavljaju brze i spore fedinge, biće dobijeni izrazi za gustinu raspodele verovatnoće i verovatnoću otkaza na izlazu iz složenog SSC/SC kombinera. Na osnovu gustine raspodele verovatnoće signala se mogu dobiti i momenti signala, veličina fedinga i verovatnoća greške po bitu, odnosno simbolu. Verovatnoće otkaza će biti grafički predstavljene, da bi se pokazala opravdanost upotrebe složenog SSC/SC kombinera u dva trenutka vremena u odnosu na klasične SSC i SC kombinere i jednokanalni prijemnik. Biće prikazana i zavisnost karakteristika sistema na izlazu od korelacije između signala u jednoj grani prijemnika između dva vremenska trenutka i kako korist od korišćenja složenog kombinera zavisi od njihove međusobne korelacije.

U šestoj glavi biće predstavljene karakteristike drugog reda SSC/SC prijemnika. Na osnovu rezultata za združene gustine raspodele verovatnoće signala i izvoda signala na izlazima iz SSC kombinera u dva trenutka vremena i izraza za združenu gustinu raspodele verovatnoće signala na izlazu, biće dobijene vrednosti za srednju učestanost preseka nivoa. Takođe će upotrebom srednje učestanosti preseka nivoa i verovatnoće otkaza biti dobijeno srednje vreme trajanja otkaza.

Na kraju je dat zaključak u kome su sumirani glavni rezultati i doprinosi ove doktorske disertacije, kao i pregled korišćene literature.

2 Karakteristike prostiranja signala u prisustvu fedinga

Prilikom prostiranja signala kroz bežične komunikacione sisteme dolazi do degradacije performansi sistema usled više različitih efekata, kao što su prostiranje signala po više putanja i efekat senke [1], koji predstavljaju veoma komplikovane pojave. Precizan matematički opis ovih pojava je ili nepoznat ili previše komplikovan za odgovarajuću sistemsku analizu, tako da se za njihovo proučavanje uvode statistički modeli feding kanala koji opisuju prostiranje signala kroz ovakve bežične komunikacione sisteme [44].

2.1 Bežični prenos signala u prisustvu fedinga

Feding je jedan od glavnoh uzroka degradacije performansi u bežičnim telekomunikacijama. U tipičnom bežičnom komunikacionom sistemu postoji više putanja signala između predajnika i prijemnika zbog rasejavanja (scattering) o različite objekte. Ti signali imaju različita slabljenja, distorzije, kašnjenja i fazne pomeraje. U prijemniku se može javiti interferencija ovih signala, koja će biti konstruktivna ili destruktivna u zavisnosti od njihove faze u trenutku superponiranja. Destruktivna interferencija izaziva značajno smanjenje snage signala. Ovaj fenomen poznat je kao feding i izaziva degradaciju performansi sistema. Vrlo često, ne samo da postoje različite putanje prenosa, već se one menjaju u vremenu. Što dovodi do vremenski promenljivog fedinga, što dodatno otežava komunikaciju, s obzirom da je ovakav feding teško modelovati [45].

Feding se može klasifikovati na više načina [44]. Ukoliko je širina frekventnog spektra signala mala u poredjenju sa širinom frekventnog opsega u okviru kojeg je feding korelisan, radi se o ravnom ili frekventno neselektivnom fedingu, gde sve frekventne komponente signala podležu istom nivou fedinga. U tom slučaju je trajanje simbola veliko u poređenju sa vremenom u okviru koga je feding korelisan. Može se smatrati da je signal u prijemniku kopija jednog signala čije su amplituda i faza odredjeni superpozicijom svih kopija signala koje stižu tokom vremena. U slučaju frekventno selektivnog fedinga, komponente signala različite frekvencije podležu različitom stepenu fedinga. Kašnjenje signala je mnogo veće od trajanja simbola, pa se primaju višestruke kopije signala.

U slučaju sporog fedinga, trajanje simbola je malo u odnosu na vreme u toku kojeg je feding korelisan. Ovakav feding se razmatra posmatranjem kanala tokom više vremenskih trenutaka, pri čemu su parametri kanala sporo promenljivi i mogu biti dobro procenjeni. U suprotnom se radi o brzom ili vremenski selektivnom fedingu, kod koga je teško proceniti parametre kanala. Može se zaključiti da ove klasifikacije zavise od karakteristika samog signala.

U bežičnom prenosu signala, i anvelopa i faza signala podležu fedingu tokom vremena. Dok fazne fluktuacije degradiraju performanse samo u koherentnim prijemnicima, s obzirom da informacije o fazi nisu potrebne kod nekoherentnih prijemnika, anvelopa fedinga utiče na karakteristike obe vrste prijemnika [1].

U zavisnosti od izgleda gustine raspodele anvelope fedinga, u literaturi postoji više modela fedinga. Dugotrajne varijacije signala opisuju se log-normalnom raspodelom, koja se može aproksimirati gamma raspodelom, radi lakših proračuna karakteristika prenosnih sistema. Kratkotrajne se opisuju nizom drugih raspodela, kao što je Rayleigh-ova, Rice-ova, Nakagami-m, ili Weibull-ova, koja je prvobitno bila namenjena teoriji pouzdanosti, pa joj se poklanjala u početki mala pažnja u teoriji telekomunikacija. Generalno je prihvaćeno da se ove raspodele koriste kada je dimenzija prostora na kome se javlja feding reda veličine nekoliko hiljada talasnih dužina, a log-normalna i gamma raspodele se koriste na većim površinama. Nijedna od navedenih raspodela se ne slaže u potpunosti sa eksperimentalnim rezultatima, mada se u blizini srednje vrednosti javlja dosta dobro slaganje. Dobro poznate raspodele fedinga izvedene su za slučajeve homogeno rasporedjenih polja rasejavanja, što je posledica slučajne raspodele objekata od kojih se vrši rasejanje. Ova predpostavka je samo aproksimacija, jer se u praksi javljaju nehomogena okruženja.

2.2 Statističke veličine za opisivanje karakteristika sistema

Momenti signala su veličine koje su korisne za izračunavanje ostalih osnovnih parametara sistema. N-ti moment signala je [35]:

$$E[r^n] = \int_0^\infty r^n p_r(r) dr \tag{2.2.1}$$

Veličina fedinga predstavlja meru osetljivosti sistema na uticaj fedinga za definisani model kanala i zavisi od trenutne vrednosti signala, a ne od snage fedinga. Veličina fedinga se definiše kao u [36]:

$$AF = \frac{E[r^2] - (E[r])^2}{(E[r])^2} = \frac{E[r^2]}{(E[r])^2} - 1 \tag{2.2.2}$$

Verovatnoća otkaza predstavlja verovatnoću da trenutna vrednost verovatnoće greške pređe određenu vrednost, odnosno da signal na izlazu iz kombinera padne ispod predefinisanog praga r_{th} [7] i upotrebljava se kao kriterijum za procenu performansi diverziti sistema koji vrše ekstrakciju signala iz feding kanala. Može se prikazati u integralnom obliku, u zavisnosti od gustine raspodele verovatnoće signala

$$P_{out} = P[r \le r_{th}] \tag{2.2.3}$$

$$P_{out} = \int_0^{r_{th}} p_r(r) dr \tag{2.2.4}$$

Srednja učestanost preseka nivoa (Level crossing rate – LCR) je učestanost kojom signal preseca odredjeni nivo, r_{th} i definiše se kao broj prolazaka trenutne vrednosti signala u jedinici vremena, kroz zadati nivo r_{th} i može se prikazati sledećom jednakošču [37]:

$$N(r_{th}) = \int_0^\infty \dot{r} p_{r,\dot{r}}(r_{th}, \dot{r}) d\dot{r} \tag{2.2.5}$$

gde je $p_{r,\dot{r}}(r_{th}, \dot{r})$ združena gustina raspodele verovatnoće signala i njegovog izvoda.

Srednje trajanje otkaza (Average outage duration – AOD) je srednje vreme za koje je vrednost signala ispod zadatog nivoa r_{th}, odnosno u stanju otkaza ili nezadovoljavajućeg prijema i određuje se kao odnos verovatnoće otkaza i srednje učestanosti preseka nivoa [38]:

$$T(r_{th}) = \frac{P_{out}}{N(r_{th})} \tag{2.2.6}$$

2.3 Diverziti sistemi

Za poboljšanje karakteristika bežičnih telekomunikacionih sistema u kanalima sa fedingom se upotrebljavaju različite diverziti tehnike [44], [46]. Povećanje ukupnog odnosa signal-šum na izlazu prijemnika, kao i povećanje verovatnoće donošenja korektne odluke o prenetom signalu se postiže prenosom L kopija željenog signala po M različitih kanala umesto prenosa signala po jednom kanalu. Dok su neke kopije podložne dubokom fedingu u jednom trenutku, druge nisu sa velikom verovatnoćom, tako da se više kopija signala se mogu dobiti ekstrakcijom signala iz različitih bežičnih putanja, na osnovu čega se razlikuju diverziti tehnike [1], [44]:

1) Frekvencijski diverziti

Signal se prenosi upotrebom M različitih frekvencijskih opsega. Nosioci su medjusobno pomereni najmanje za frekventni opseg (Δf)c u kome je feding korelisan, tako da su različite kopije medjusobno nezavisne u pogledu fedinga. U prijemniku se kombinuje L nezavisnih kopija signala sa fedingom da bi se dobio statistički optimalni signal za odlučivanje. Ova tehnika se uglavnom koristi za frekventno selektivni feding [44].

2) Vremenski diverziti

Više kopija istog signala se prenosi u M različitih perioda vremena tj. svaki simbol se prenosi M puta. Intervali izmedju prenošenja istog simbola treba da budu veći ili jednaki vremenu koherencije (Δt)c, tako da su različite kopije medjusobno nezavisne u pogledu fedinga. Optimalno kombinovanje postiže se MRC kombinerom. Može se zapaziti i da slanje istog simbola M puta odgovara trivijalnom kodovanju. Takodje, može se koristiti i netrivijalno kodovanje sa kontrolom greške i interliving. Ova tehnika je pogodna za vremenski selektivni (brzi) feding [44].

3) Prostorni diverziti

M kopija signala koji se prenosi po različitim prostornim putanjama, dok se pri prijemu koristi M antena. One se moraju nalaziti na dovoljnom rastojanju da bi primljene kopije signala bile nezavisne u pogledu fedinga. Za razliku od frekventnog i vremenskog diverzita ne zahteva se dodatni napor u predajniku, niti dodatni propusni opseg i dodatno vreme prenosa. Ipak, fizičke smetnje ograničavaju njegovu upotrebu. Ponekad se koristi i veći broj antena na predaji. Prostorni diverzit je pogodan i za frekventno selektivni feding i za vremenski selektivni feding [44].

4) Polarizacioni diverziti

Kopije signala se emituju i primaju antenama sa različitom polarizacijom. Na ovaj način, postiže se efekat diverzita s obzirom da vertikalno i horizontalno polarisane komponente podležu različitom stepenu fedinga. Prednosti u odnosu na prostorni diverzit su što se antene mogu instalirati jedna pored druge na istom mestu i nije potreban dodatni spektar. Osnovne mane su što se mogu realizovati samo sistemi sa dve grane i što se emitovanje vrši snagom za 3 dB većom nego kod ostalih tehnika, jer se signalom napajaju obe polarizacione antene u predajniku [44].

5) Ugaoni (direkcioni) diverziti

Primljeni signal sastoji se od komponenti nastalih refleksijom, difrakcijom ili rasejanjem, koje dolaze iz različitih pravaca (uglova). Korišćenjem jako usmerenih antena, moguće je razložiti primljeni signal na veći broj signala, koji se mogu smatrati medjusobno nezavisnim signalima sa fedingom, čime se ostvaruje diverziti prijem [44].

6) Diverziti po putanjama

U slučaju ove tehnike se vrši razlaganje direktne komponente i zakašnjenih komponenti i njihovo koherentno kombinovanje. Tipičan primer je RAKE prijemnik (ovaj prijemnik podseća na grabulje jer poseduje krak za svaku komponentu primljenog signala) [44].

2.4 Tehnike za kombinovanje

Primena diverziti sistema je jedna od najefikasnijih metoda za prevazilaženje degradacija signala nastalih usled fedinga. U prijemnicima diverziti sistema se vrši kombinovanje više kopija signala koji se prenosi, a koje podležu fedingu na međusobno nezavistan način, čime se uvećava ukupna primljena snaga signala. Kombinovanje u diverziti sistemima je efikasan način da se poboljša odnos signal-šum (SNR) primljenog signala, zato što signal na izlazu iz kombinera ima veći SNR nego SNR u svim pojedinačnim granama prijemnika. Postoji više osnovnih i hibridnih metoda za izdvajanje korisnog signala [47]. Različiti tipovi diverziti sistema zahtevaju različite tehnike kombinovanja. Najčešće se primenju sledeći tipovi kombinovanja [1], [44]:

1) MRC - Kombinovanje sa maksimalnim odnosom

(maximal ratio combining - MRC) je optimalna komunaciona tehnika u odsustvu interferencije, nezavisno od karakteristika feding kanala. Ova tehnika zahteva kompleksan kombiner, jer je potrebno poznavati sve feding parametre kanala. Grane kombinera su ponderisane tako da se dobije maksimalni SNR. Kad postoje dva ulaza, gustina verovatnoće odnosa snage signala i šuma na izlazu iz kombinera jednaka je konvoluciji gustina verovatnoća odnosa snage signala i šuma na njegovim ulazima. Zbog neophodnosti poznavanja parametara feding kanala ova tehnika je pogodna za primenu sistemima u kojima se koriste amplitudna i fazna modulacija, dok je manje praktična za sisteme sa diferencijalnom koherentnom i nekoherentnom detekcijom.

2) EGC - Kombinovanje sa istom težinom

(equal gain combining - EGC) tehnika kombinovanja je slična MRC tehnici, ali je manje efikasna od nje. Često se koristi, jer ne zahteva određivanje vrednosti feding amplitude, tako da je kombinovanje manje kompleksno od MRC tehnike, uz nešto slabije rezultate.

3) SC - Kombinovanje sa selekcijom

(selection combining - SC) procesira samo jednu granu prijamnika u jednom vremenskom trenutku, za razliku od MRC i EGC, koji vrše obradu na osnovu kopija signala u svim granama. U slučaju SC kombinera bira se grana sa najvećim odnosom signal-šum. SC se uglavnom koristi sa diferencijalnom koherentnom i nekoherentnom detekcijom, jer ne zahteva poznavanje faza signala u granama kombinera.

4) SSC, SEC - Kombinovanje sa prebacivanjem

(switch and stay combining - SSC, switch and examine combinig - SEC) su pogodne za primenu kod sistema sa neprekidnim prenosom. Da bi se izbeglo simultano i kontinualno praćenje stanja na svim granama, SC se često zamenjuje ovom tehnikom. U ovom slučaju prijemnik nije uvek vezan za najbolju granu, već je vezan na istu granu, sve dok SNR te grane ne padne ispod praga. Kad se to desi, prijemnik jednostavno bira sledeću granu. S ovim pristupom, prijemnik u bilo kom trenutku prati stanje na trenutno selektovanoj grani. Ovim se smanjuje kompleksnost u odnosu na SC, ali dolazi do izvesnog gubitka kvaliteta. Osnovni problem je izbor optimalnog praga dovoljno visokog da spreči da se uvek skida signal sa iste grane i dovoljno niskog da se izbegne kontinualno prebacivanje izmedju grana. Pokazuje se da postoji optimalni prag u pogledu minimalnog BER-a i zavisi od srednje snage fedinga.

5) GSC - Generalizovane diverziti tehnike

(Generalized Diversity Techniques - GSC) predstavljaju hibridne tehnike kombinovanja i uvedene su zbog velikog povećanja složenosti MRC i EGC prijemnika sa povećanjem broja grana. U ovom slučaju GSC između grana prijemnika adaptivno kombinuje (MRC ili EGC tehnikom) grana sa najvećim odnosom signal-šum na prijemu. Ove tehnike se označavaju kao SC/MRC ili SC/EGC .

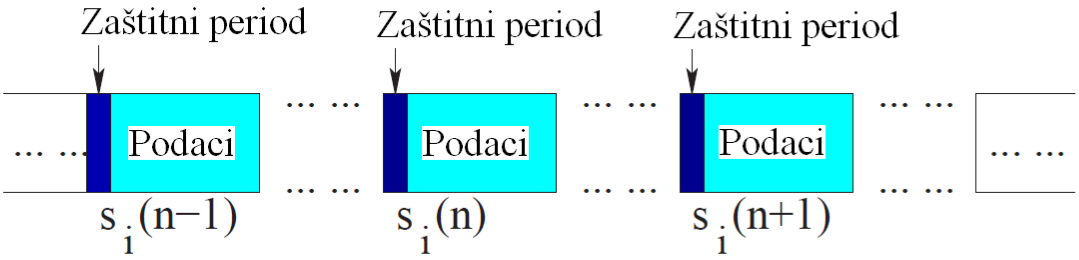
6) Multidimenzionalne diverziti tehnike

Ove tehnike uključuju kombinaciju dva ili više načina za postizanje diverziti efekta, kao na primer prostorni i diverzit po putanjama u cilju dobijanja boljih karakteristika prijemnika. Jedan od primera je prenos u širokopojasnoj CDMA tehnici gde u prijemniku postoje dvodimenzionalni RAKE prijemnici. RAKE prijemnici se sastoje od polja antena od kojih je svaka praćena konvencionalnim RAKE prijemnikom. Ovakav način prenosa se može generalizovati na istovremenu primenu prostornog, frekvencijskog i diverzita po putanjama.

2.5 Odmeravanje signala u prijemnicima bežičnih telekomunikacionih sistema

Vremenski okvir kod bežičnog prenosa digitalnih podataka se može podeliti na zaštitne periode u kojima nema prenosa korisnih podataka i sistem vrši neophodna podešavanja i periode za prenos podataka [48]. Na slici 2.5.1. je prikazana struktura vremenskog okvira kod bežičnog prenosa podataka.

Za ovakve sisteme važi da se kombinovanje u prijemnicima vrši jedino za vreme zaštitnih perioda. U svakom zaštitnom periodu prijemnik vrši procenu stanja kanala i obavlja proračune, na osnovu kojih donosi odluku, koja za SSC kombiner predstavlja granu sa koje se signal prenosi na izlaz iz kombinera, odnosno da li će doći do prebacivanja sa grane na granu. Ovaj princip važi i za uplink i za downlink.



Slika 2.5.1. Struktura vremenskog okvira kod bežičnog prenosa podataka

Sistem radi pod pretpostavkama da je feding sporo promenjiv, tako da se može smatrati da je raspodela fedinga ista kao u prethodnom zaštitnom periodu, kao i da su signali za vreme dva sukcesivna zaštitna perioda skoro nezavisni.

U klasičnim prijemnicima se odmeravanje signala na ulaznim granama prijemnika vrši jednom u svakom zaštitnom periodu. U ovoj disertaciji će biti predstavljen sistem u kome se odmeravanje vrši dva puta u toku jednog zaštitnog intervala, gde signali na ulazu jedne grane u dva trenutka vremena mogu biti korelisani.

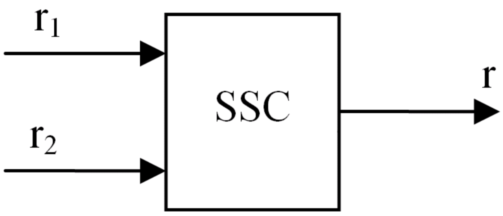
3 Karakteristike SSC kombinera

Kombinovanje sa prebacivanjem (SSC) je pokušaj uprošćavanja složenosti sistema, ali sa gubitkom performansi u odnosu na složenije tipove diverziti prijemnika. U ovom slučaju prijemnik selektuje jednu antenu sve dok kvalitet signala na njenom ulazu ne padne ispod nekog predefinisanog je praga. Kada se to desi, prijemnik se prebacuje na drugu antenu i koristi podatke sa nje u sledećem semplu, bez obzira na to da li je kvalitet signala na anteni iznad ili ispod predefinisanog praga. Razmatranje SSC sistema u literaturi je ograničeno na manje kompleksne mobilne jedinice gde broj diverziti antena obično ograničen na 2 [14], [49], [50]. Ovo uzrokuje smanjenje kompleksnosti u odnosu na SC kombinere, jer nije potrebno istovremeno pratiti obe grane prijemnika.

3.1 Model sistema u jednom trenutku vremena

Razmatra se SSC kombiner sa dva ulaza. Model ovog sistema je prikazan na slici 3.1.1. Verovatnoća događaja da kombiner prvo ispituje signal na prvom ulazu je P_1, a na drugom ulazu je P_2. Ako kombiner prvo ispituje signal na prvom ulazu i vrednost signala r_1 je iznad praga r_T, SSC kombiner propušta signal u kolo za odlučivanje. Ako je vrednost signala na prvom ulazu ispod praga r_T, SSC kombiner propušta signal sa drugog ulaza u kolo za odlučivanje, bez obzira da li je r_2 iznad ili ispod predefinisanog praga. Ako SSC kombiner prvo ispituje signal sa druge grane, logika odlučivanja je ekvivalentna prvom slučaju. Prvo se ispituje signal na drugom ulazu i ako je vrednost signala r_2 iznad praga r_T, SSC kombiner propušta signal u kolo za odlučivanje, a ako je vrednost signala na drugom ulazu ispod praga

r_T, SSC kombiner propušta signal sa prvog ulaza u kolo za odlučivanje, bez obzira da li je r_1 iznad ili ispod predefinisanog praga.



Slika 3.1.1. Model SSC kombinera sa dva ulaza u jednom trenutku vremena

Izraz za gustinu raspodele verovatnoće signala na izlazu iz kombinera će prvo biti određen za slučaj $r<r_T$. Na osnovu algoritma rada SSC kombinera u ovom slučaju, gustina raspodele verovatnoće je:

$$p_r(r) = P_1 F_{r_1}(r_T) p_{r_2}(r) + P_2 F_{r_2}(r_T) p_{r_1}(r) \tag{3.1.1}$$

Za slučaj $r \geq r_T$, gustina raspodele verovatnoće na izlazu iz kombinera je:

$$p_r(r) = P_1 p_{r_1}(r) + P_1 F_{r_1}(r_T) p_{r_2}(r) + P_2 p_{r_2}(r) + P_2 F_{r_2}(r_T) p_{r_1}(r) \tag{3.1.2}$$

gde je r_T prag odluke, a kumulativne raspodele verovatnoće su date kao [1]:

$$F_{r_1}(r_T) = \int_0^{r_T} p_{r_1}(x)\,dx \tag{3.1.3}$$

$$F_{r_2}(r_T) = \int_0^{r_T} p_{r_2}(x)\,dx \tag{3.1.4}$$

Verovatnoće P_1 i P_2 su [1]:

$$P_1 = P_1 \left(1 - F_{r_1}(r_T)\right) + P_2 F_{r_2}(r_T) \tag{3.1.5}$$

$$P_2 = P_2 \left(1 - F_{r_2}(r_T)\right) + P_1 F_{r_1}(r_T) \tag{3.1.6}$$

Na osnovu (3.1.5-6) dobijaju se P_1 i P_2 u zavisnosti od kumulativne raspodele verovatnoće:

$$P_1 = \frac{F_{r_2}(r_T)}{F_{r_1}(r_T) + F_{r_2}(r_T)} \tag{3.1.7}$$

$$P_2 = \frac{F_{r_1}(r_T)}{F_{r_1}(r_T) + F_{r_2}(r_T)} \tag{3.1.8}$$

3.2 Model sistema u dva trenutka vremena

U ovom poglavlju se razmatra SSC kombiner sa dve grane u dva trenutka vremena. Model sistema je prikazan na slici 3.2.1. Signali na ulazima su r_{11} i r_{21} u prvom trenutku vremena, a r_{12} i r_{22} u drugom trenutku vremena. Signali na izlazu su r_1 i r_2. Indeksi za ulazne signale su: prvi indeks je broj grane, a drugi razmatran vremenski trenutak. Za izlazni signal, indeks predstavlja razmatrani vremenski trenutak. Verovatnoća da kombiner prvo razmatra signal na prvoj grani je P_1, a na drugoj je P_2.

Za $r_1<r_T$, $r_2<r_T$

U ovom slučaju svi signali su manji od praga r_T, odnosno: $r_{11}<r_T$, $r_{12}<r_T$ $r_{21}<r_T$, $r_{22}<r_T$. Neka kombiner prvo razmatra signal r_{11}. Pošto je $r_{11}<r_T$, onda je $r_1=r_{21}$, a kako je $r_{22}<r_T$, onda je $r_2=r_{12}$. Verovatnoća ovog događaja je P_1. Kada kombiner prvo razmatra signal r_{21}, onda važi da je $r_{21}<r_T$, $r_1=r_{11}$, kao i $r_{21}<r_T$, $r_2=r_{22}$. Verovatnoća ovog događaja je P_2.

- $r_{11}<r_T$, $r_{21}<r_T$, $r_{22}<r_T$, $r_{12}<r_T$, $r_1=r_{21}$ $r_2=r_{12}$ P_1
- $r_{21}<r_T$, $r_{11}<r_T$, $r_{12}<r_T$, $r_{22}<r_T$, $r_1=r_{11}$ $r_2=r_{22}$ P_2

Za $r_1\geq r_T$, $r_2<r_T$

Moguće kobinacije su:

- $r_{11}\geq r_T$, $r_{12}<r_T$, $r_{22}<r_T$, $r_1=r_{11}$ $r_2=r_{22}$ P_1
- $r_{11}<r_T$, $r_{21}\geq r_T$, $r_{22}<r_T$, $r_{12}<r_T$, $r_1=r_{21}$ $r_2=r_{12}$ P_1
- $r_{21}\geq r_T$, $r_{22}<r_T$, $r_{12}<r_T$, $r_1=r_{21}$ $r_2=r_{12}$ P_2
- $r_{21}<r_T$, $r_{11}\geq r_T$, $r_{12}<r_T$, $r_{22}<r_T$, $r_1=r_{11}$ $r_2=r_{22}$ P_2

Za $r_1<r_T$, $r_2\geq r_T$

Moguće kobinacije su:

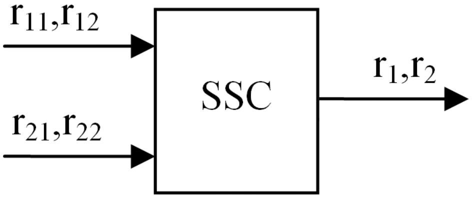
- $r_{11}<r_T$, $r_{21}<r_T$, $r_{22}\geq r_T$, $r_1=r_{21}$ $r_2=r_{22}$ P_1
- $r_{11}<r_T$, $r_{21}<r_T$, $r_{22}<r_T$, $r_{12}\geq r_T$, $r_1=r_{21}$ $r_2=r_{12}$ P_1
- $r_{21}<r_T$, $r_{11}<r_T$, $r_{12}\geq r_T$, $r_1=r_{11}$ $r_2=r_{12}$ P_2
- $r_{21}<r_T$, $r_{11}<r_T$, $r_{12}<r_T$, $r_{22}\geq r_T$, $r_1=r_{11}$ $r_2=r_{22}$ P_2

Za $r_1\geq r_T$, $r_2\geq r_T$

Moguće kobinacije su:

- $r_{11}\geq r_T$, $r_{12}\geq r_T$, $r_1=r_{11}$ $r_2=r_{12}$ P_1
- $r_{11}\geq r_T$, $r_{12}<r_T$, $r_{22}\geq r_T$ $r_1=r_{11}$ $r_2=r_{22}$ P_1
- $r_{11}<r_T$, $r_{21}\geq r_T$, $r_{22}\geq r_T$, $r_1=r_{21}$ $r_2=r_{22}$ P_1
- $r_{11}<r_T$, $r_{21}\geq r_T$, $r_{22}<r_T$, $r_{12}\geq r_T$ $r_1=r_{21}$ $r_2=r_{12}$ P_1

- $r_{21} \geq r_T$, $r_{22} \geq r_T$, $r_1 = r_{21}$ $r_2 = r_{22}$ P_2
- $r_{21} \geq r_T$, $r_{22} < r_T$, $r_{12} \geq r_T$, $r_1 = r_{21}$ $r_2 = r_{12}$ P_2
- $r_{21} < r_T$, $r_{11} \geq r_T$, $r_{12} \geq r_T$, $r_1 = r_{11}$ $r_2 = r_{12}$ P_2
- $r_{21} < r_T$, $r_{11} \geq r_T$, $r_{12} < r_T$, $r_{22} \geq r_T$, $r_1 = r_{11}$ $r_2 = r_{22}$ P_2



Slika 3.2.1. Model SSC kombinera sa dva ulaza u dva trenutka vremena

Za $r_1 < r_T$, $r_2 < r_T$

$$p_{r_1r_2}(r_1,r_2) = P_1\int_0^{r_T} dr_{11}\int_0^{r_T} dr_{22}\, p_{r_{11}r_{22}r_{21}r_{12}}(r_{11},r_{22},r_1,r_2) + P_2\int_0^{r_T} dr_{21}\int_0^{r_T} dr_{12}\, p_{r_{21}r_{12}r_{11}r_{22}}(r_{21},r_{12},r_1,r_2) \quad (3.2.1)$$

Za $r_1 \geq r_T$, $r_2 < r_T$

$$p_{r_1r_2}(r_1,r_2) = P_1\int_0^{r_T} dr_{12}\, p_{r_{12}r_{11}r_{22}}(r_{12},r_1,r_2) + P_1\int_0^{r_T} dr_{11}\int_0^{r_T} dr_{22}\, p_{r_{11}r_{22}r_{21}r_{12}}(r_{11},r_{22},r_1,r_2) +$$

$$+ P_2\int_0^{r_T} dr_{22}\, p_{r_{22}r_{21}r_{12}}(r_{22},r_1,r_2) + P_2\int_0^{r_T} dr_{21}\int_0^{r_T} dr_{12}\, p_{r_{21}r_{12}r_{11}r_{22}}(r_{21},r_{12},r_1,r_2) \quad (3.2.2)$$

Za $r_1 < r_T$, $r_2 \geq r_T$

$$p_{r_1r_2}(r_1,r_2) = P_1\int_0^{r_T} dr_{11}\, p_{r_{11}r_{21}r_{22}}(r_{11},r_1,r_2) + P_1\int_0^{r_T} dr_{11}\int_0^{r_T} dr_{22}\, p_{r_{11}r_{22}r_{21}r_{12}}(r_{11},r_{22},r_1,r_2) +$$

$$+ P_2\int_0^{r_T} dr_{21}\, p_{r_{21}r_{11}r_{12}}(r_{21},r_1,r_2) + P_2\int_0^{r_T} dr_{21}\int_0^{r_T} dr_{12}\, p_{r_{21}r_{12}r_{11}r_{22}}(r_{21},r_{12},r_1,r_2) \quad (3.2.3)$$

Za $r_1 \geq r_T$, $r_2 \geq r_T$

$$p_{r_1r_2}(r_1,r_2) = P_1 p_{r_{11}r_{12}}(r_1,r_2) + P_1\int_0^{r_T} dr_{12}\, p_{r_{12}r_{11}r_{22}}(r_{12},r_1,r_2) +$$

$$+ P_1\int_0^{r_T} dr_{11}\, p_{r_{11}r_{21}r_{22}}(r_{11},r_1,r_2) + P_1\int_0^{r_T} dr_{11}\int_0^{r_T} dr_{22}\, p_{r_{11}r_{22}r_{21}r_{12}}(r_{11},r_{22},r_1,r_2) +$$

$$+P_2 p_{r_{21}r_{22}}(r_1,r_2)+P_2\int_0^{r_T} dr_{22}\, p_{r_{22}r_{21}r_{12}}(r_{22},r_1,r_2)+$$

$$+P_2\int_0^{r_T} dr_{21}\, p_{r_{21}r_{11}r_{12}}(r_{21},r_1,r_2)+P_2\int_0^{r_T} dr_{21}\int_0^{r_T} dr_{12}\, p_{r_{21}r_{12}r_{11}r_{22}}(r_{21},r_{12},r_1,r_2) \qquad (3.2.4)$$

Kada su signali na ulazu u grane kombinera nekorelisani, PDF se može predstaviti u obliku:

Za $r_1<r_T$, $r_2<r_T$

$$p_{r_1r_2}(r_1,r_2)=P_1\int_0^{r_T} p_{r_{11}r_{12}}(r_{11},r_2)dr_{11}\int_0^{r_T} p_{r_{22}r_{21}}(r_{22},r_1)dr_{22}+P_2\int_0^{r_T} p_{r_{21}r_{22}}(r_{21},r_2)dr_{21}\int_0^{r_T} p_{r_{12}r_{11}}(r_{12},r_1)dr_{12}$$

(3.2.5)

Za $r_1\geq r_T$, $r_2<r_T$

$$p_{r_1r_2}(r_1,r_2)=P_1 p_{r_{22}}(r_2)\int_0^{r_T} p_{r_{12}r_{11}}(r_{12},r_1)dr_{12}+P_1\int_0^{r_T} p_{r_{11}r_{12}}(r_{11},r_2)dr_{11}\int_0^{r_T} p_{r_{22}r_{21}}(r_{22},r_1)dr_{22}+$$

$$+P_2 p_{r_{12}}(r_2)\int_0^{r_T} p_{r_{22}r_{21}}(r_{22},r_1)dr_{22}+P_2\int_0^{r_T} p_{r_{21}r_{22}}(r_{21},r_2)dr_{21}\int_0^{r_T} p_{r_{12}r_{11}}(r_{12},r_1)dr_{12} \qquad (3.2.6)$$

Za $r_1<r_T$, $r_2\geq r_T$

$$p_{r_1r_2}(r_1,r_2)=P_1\int_0^{r_T} p_{r_{11}}(r_{11})dr_{11}\, p_{r_{21}r_{22}}(r_1,r_2)+P_1\int_0^{r_T} p_{r_{11}r_{12}}(r_{11},r_2)dr_{11}\int_0^{r_T} p_{r_{22}r_{21}}(r_{22},r_1)dr_{22}+$$

$$+P_2\int_0^{r_T} p_{r_{21}}(r_{21})dr_{21}\, p_{r_{11}r_{12}}(r_1,r_2)+P_2\int_0^{r_T} p_{r_{21}r_{22}}(r_{21},r_2)dr_{21}\int_0^{r_T} p_{r_{12}r_{11}}(r_{12},r_1)dr_{12} \qquad (3.2.7)$$

Za $r_1\geq r_T$, $r_2\geq r_T$

$$p_{r_1r_2}(r_1,r_2)=P_1 p_{r_{11}r_{12}}(r_1,r_2)+P_1 p_{r_{22}}(r_2)\int_0^{r_T} p_{r_{12}r_{11}}(r_{12},r_1)dr_{12}+$$

$$+P_1\int_0^{r_T} p_{r_{11}}(r_{11})dr_{11}\, p_{r_{21}r_{22}}(r_1,r_2)+P_1\int_0^{r_T} p_{r_{11}r_{12}}(r_{11},r_2)dr_{11}\int_0^{r_T} p_{r_{22}r_{21}}(r_{22},r_1)dr_{22}+$$

$$+P_2 p_{r_{21}r_{22}}(r_1,r_2)+P_2 p_{r_{12}}(r_2)\int_0^{r_T} p_{r_{22}r_{21}}(r_{22},r_1)dr_{22}+$$

$$+P_2\int_0^{r_T} p_{r_{21}}(r_{21})dr_{21}\, p_{r_{11}r_{12}}(r_1,r_2)+P_2\int_0^{r_T} p_{r_{21}r_{22}}(r_{21},r_2)dr_{21}\int_0^{r_T} p_{r_{12}r_{11}}(r_{12},r_1)dr_{12} \qquad (3.2.8)$$

3.3 Združena gustina raspodele verovatnoće na izlazu SSC kombinera u dva trenutka vremena u prisustvu Rayleigh-jevog fedinga

Gustina raspodele verovatnoće i kumulativna raspodela verovatnoće (CDF) signala na ulazima u grane kombinera $r_{i,j}$ u prisustvu Rayleigh-jevog fedinga su [5]:

$$p_{r_i}(r_{i,j}) = \frac{r_{i,j}}{\sigma_i^2} e^{-\frac{r_{i,j}^2}{2\sigma_i^2}} \quad , \quad r_{i,j} \geq 0 \tag{3.3.1}$$

$$F_{r_i}(r_{i,j}) = 1 - e^{-\frac{r_{i,j}^2}{2\sigma_i^2}} \quad , \quad r_{i,j} \geq 0 \tag{3.3.2}$$

gde su $i=1,2$ $j=1,2$ i σ je standardna devijacija raspodele.

Verovatnoće P_1 i P_2 se dobijaju ako se u (3.1.17-18) stavi (3.3.2):

$$P_1 = \frac{F_{r_2}(r_T)}{F_{r_1}(r_T) + F_{r_2}(r_T)} = \frac{1 - e^{-\frac{r_T^2}{2\sigma_2^2}}}{2 - \left(e^{-\frac{r_T^2}{2\sigma_1^2}} + e^{-\frac{r_T^2}{2\sigma_2^2}} \right)} \tag{3.3.3}$$

$$P_2 = \frac{F_{r_1}(r_T)}{F_{r_1}(r_T) + F_{r_2}(r_T)} = \frac{1 - e^{-\frac{r_T^2}{2\sigma_1^2}}}{2 - \left(e^{-\frac{r_T^2}{2\sigma_1^2}} + e^{-\frac{r_T^2}{2\sigma_2^2}} \right)} \tag{3.3.4}$$

Združena gustina raspodele verovatnoće korelisanih signala x_1 i x_2 sa Rayleigh-jevom raspodelom i istim parametrom σ je [19]:

$$p_{x_1 x_2}(x_1, x_2) = \frac{x_1 x_2}{\sigma^4 (1-\rho^2)} e^{-\frac{x_1^2 + x_2^2}{2\sigma^2 (1-\rho^2)}} I_0\left(\frac{\rho x_1 x_2}{\sigma^2 (1-\rho^2)} \right) \tag{3.3.5}$$

gde je ρ koeficijent korelacije, a $I_0(\ )$ je modifikovana Bessel-ova funkcija prve vrste nultog reda [51].

Združena gustina raspodele verovatnoće signala r_1 i r_2 na izlazu SSC kombinera u dva trenutka vremena u prisustvu Rayleigh-jevog fedinga kada su signali na ulazu u grane kombinera nezavisni, može se dobiti ako se u (3.2.5-8) stave izrazi (3.3.1) i (3.3.5), gde su P_1 i P_2 definisane sa (3.2.3-4):

Za $r_1 < r_T$, $r_2 < r_T$

$$p_{r_1 r_2}(r_1, r_2) =$$

$$= P_1 \int_0^{r_T} \frac{r_{11} r_2}{\sigma_1^4 (1-\rho_1^2)} e^{-\frac{r_{11}^2 + r_2^2}{2\sigma_1^2 (1-\rho_1^2)}} I_0\left(\frac{\rho_1 r_{11} r_2}{\sigma_1^2 (1-\rho_1^2)} \right) dr_{11} \int_0^{r_T} \frac{r_{22} r_1}{\sigma_2^4 (1-\rho_2^2)} e^{-\frac{r_{22}^2 + r_1^2}{2\sigma_2^2 (1-\rho_2^2)}} I_0\left(\frac{\rho_2 r_{22} r_1}{\sigma_2^2 (1-\rho_2^2)} \right) dr_{22} +$$

$$+ P_2 \int_0^{r_T} \frac{r_{21} r_2}{\sigma_2^4 (1-\rho_2^2)} e^{-\frac{r_{21}^2 + r_2^2}{2\sigma_2^2 (1-\rho_2^2)}} I_0\left(\frac{\rho_2 r_{21} r_2}{\sigma_2^2 (1-\rho_2^2)} \right) dr_{21} \int_0^{r_T} \frac{r_{12} r_1}{\sigma_1^4 (1-\rho_1^2)} e^{-\frac{r_{12}^2 + r_1^2}{2\sigma_1^2 (1-\rho_1^2)}} I_0\left(\frac{\rho_1 r_{12} r_1}{\sigma_1^2 (1-\rho_1^2)} \right) dr_{12} \tag{3.3.6}$$

Za $r_1 \geq r_T$, $r_2 < r_T$

$$p_{r_1 r_2}(r_1, r_2) = P_1 \frac{r_2}{\sigma_2^2} e^{-\frac{r_2^2}{2\sigma_2^2}} \int_0^{r_T} \frac{r_{12} r_1}{\sigma_1^4 (1-\rho_1^2)} e^{-\frac{r_{12}^2 + r_1^2}{2\sigma_1^2 (1-\rho_1^2)}} I_0\left(\frac{\rho_1 r_{12} r_1}{\sigma_1^2 (1-\rho_1^2)} \right) dr_{12} +$$

$$+ P_1 \int_0^{r_T} \frac{r_{11} r_2}{\sigma_1^4 (1-\rho_1^2)} e^{-\frac{r_{11}^2 + r_2^2}{2\sigma_1^2 (1-\rho_1^2)}} I_0\left(\frac{\rho_1 r_{11} r_2}{\sigma_1^2 (1-\rho_1^2)} \right) dr_{11} \int_0^{r_T} \frac{r_{22} r_1}{\sigma_2^4 (1-\rho_2^2)} e^{-\frac{r_{22}^2 + r_1^2}{2\sigma_2^2 (1-\rho_2^2)}} I_0\left(\frac{\rho_2 r_{22} r_1}{\sigma_2^2 (1-\rho_2^2)} \right) dr_{22} +$$

$$+ P_2 \frac{r_2}{\sigma_1^2} e^{-\frac{r_2^2}{2\sigma_1^2}} \int_0^{r_T} \frac{r_{22} r_1}{\sigma_2^4 (1-\rho_2^2)} e^{-\frac{r_{22}^2 + r_1^2}{2\sigma_2^2 (1-\rho_2^2)}} I_0\left(\frac{\rho_2 r_{22} r_1}{\sigma_2^2 (1-\rho_2^2)} \right) dr_{22} +$$

$$+ P_2 \int_0^{r_T} \frac{r_{21} r_2}{\sigma_2^4 (1-\rho_2^2)} e^{-\frac{r_{21}^2 + r_2^2}{2\sigma_2^2 (1-\rho_2^2)}} I_0\left(\frac{\rho_2 r_{21} r_2}{\sigma_2^2 (1-\rho_2^2)} \right) dr_{21} \int_0^{r_T} \frac{r_{12} r_1}{\sigma_1^4 (1-\rho_1^2)} e^{-\frac{r_{12}^2 + r_1^2}{2\sigma_1^2 (1-\rho_1^2)}} I_0\left(\frac{\rho_1 r_{12} r_1}{\sigma_1^2 (1-\rho_1^2)} \right) dr_{12} \tag{3.3.7}$$

Za $r_1 < r_T$, $r_2 \geq r_T$

$$p_{r_1 r_2}(r_1, r_2) = P_1 \left(1 - e^{-\frac{r_T^2}{2\sigma_1^2}} \right) \frac{r_1 r_2}{\sigma_2^4 (1-\rho_2^2)} e^{-\frac{r_1^2 + r_2^2}{2\sigma_2^2 (1-\rho_2^2)}} I_0\left(\frac{\rho_2 r_1 r_2}{\sigma_2^2 (1-\rho_2^2)} \right) +$$

$$+ P_1 \int_0^{r_T} \frac{r_{11} r_2}{\sigma_1^4 (1-\rho_1^2)} e^{-\frac{r_{11}^2 + r_2^2}{2\sigma_1^2 (1-\rho_1^2)}} I_0\left(\frac{\rho_1 r_{11} r_2}{\sigma_1^2 (1-\rho_1^2)} \right) dr_{11} \int_0^{r_T} \frac{r_{22} r_1}{\sigma_2^4 (1-\rho_2^2)} e^{-\frac{r_{22}^2 + r_1^2}{2\sigma_2^2 (1-\rho_2^2)}} I_0\left(\frac{\rho_2 r_{22} r_1}{\sigma_2^2 (1-\rho_2^2)} \right) dr_{22} +$$

$$+ P_2 \left(1 - e^{-\frac{r_T^2}{2\sigma_2^2}} \right) \frac{r_1 r_2}{\sigma_1^4 (1-\rho_1^2)} e^{-\frac{r_1^2 + r_2^2}{2\sigma_1^2 (1-\rho_1^2)}} I_0\left(\frac{\rho_1 r_1 r_2}{\sigma_1^2 (1-\rho_1^2)} \right) +$$

$$+ P_2 \int_0^{r_T} \frac{r_{21} r_2}{\sigma_2^4 (1-\rho_2^2)} e^{-\frac{r_{21}^2 + r_2^2}{2\sigma_2^2 (1-\rho_2^2)}} I_0\left(\frac{\rho_2 r_{21} r_2}{\sigma_2^2 (1-\rho_2^2)} \right) dr_{21} \int_0^{r_T} \frac{r_{12} r_1}{\sigma_1^4 (1-\rho_1^2)} e^{-\frac{r_{12}^2 + r_1^2}{2\sigma_1^2 (1-\rho_1^2)}} I_0\left(\frac{\rho_1 r_{12} r_1}{\sigma_1^2 (1-\rho_1^2)} \right) dr_{12} \tag{3.3.8}$$

Za $r_1 \geq r_T$, $r_2 \geq r_T$

$$
\begin{aligned}
p_{r_1 r_2}(r_1, r_2) = {} & P_1 \frac{r_1 r_2}{\sigma_1^4(1-\rho_1^2)} e^{-\frac{r_1^2+r_2^2}{2\sigma_1^2(1-\rho_1^2)}} I_0\left(\frac{\rho_1 r_1 r_2}{\sigma_1^2(1-\rho_1^2)}\right) + \\
& + P_1 \frac{r_2}{\sigma_2^2} e^{-\frac{r_2^2}{2\sigma_2^2}} \int_0^{r_T} \frac{r_{12} r_1}{\sigma_1^4(1-\rho_1^2)} e^{-\frac{r_{12}^2+r_1^2}{2\sigma_1^2(1-\rho_1^2)}} I_0\left(\frac{\rho_1 r_{12} r_1}{\sigma_1^2(1-\rho_1^2)}\right) dr_{12} + \\
& + P_1 \left(1 - e^{-\frac{r_T^2}{2\sigma_1^2}}\right) \frac{r_1 r_2}{\sigma_2^4(1-\rho_2^2)} e^{-\frac{r_1^2+r_2^2}{2\sigma_2^2(1-\rho_2^2)}} I_0\left(\frac{\rho_2 r_1 r_2}{\sigma_2^2(1-\rho_2^2)}\right) + \\
& + P_1 \int_0^{r_T} \frac{r_{11} r_2}{\sigma_1^4(1-\rho_1^2)} e^{-\frac{r_{11}^2+r_2^2}{2\sigma_1^2(1-\rho_1^2)}} I_0\left(\frac{\rho_1 r_{11} r_2}{\sigma_1^2(1-\rho_1^2)}\right) dr_{11} \int_0^{r_T} \frac{r_{22} r_1}{\sigma_2^4(1-\rho_2^2)} e^{-\frac{r_{22}^2+r_1^2}{2\sigma_2^2(1-\rho_2^2)}} I_0\left(\frac{\rho_2 r_{22} r_1}{\sigma_2^2(1-\rho_2^2)}\right) dr_{22} + \\
& + P_2 \frac{r_1 r_2}{\sigma_2^4(1-\rho_2^2)} e^{-\frac{r_1^2+r_2^2}{2\sigma_2^2(1-\rho_2^2)}} I_0\left(\frac{\rho_2 r_1 r_2}{\sigma_2^2(1-\rho_2^2)}\right) + \\
& + P_2 \frac{r_2}{\sigma_1^2} e^{-\frac{r_2^2}{2\sigma_1^2}} \int_0^{r_T} \frac{r_{22} r_1}{\sigma_2^4(1-\rho^2)} e^{-\frac{r_{22}^2+r_1^2}{2\sigma_2^2(1-\rho^2)}} I_0\left(\frac{\rho r_{22} r_1}{\sigma_2^2(1-\rho^2)}\right) dr_{22} + \\
& + P_2 \left(1 - e^{-\frac{r_T^2}{2\sigma_2^2}}\right) \frac{r_1 r_2}{\sigma_1^4(1-\rho_1^2)} e^{-\frac{r_1^2+r_2^2}{2\sigma_1^2(1-\rho_1^2)}} I_0\left(\frac{\rho_1 r_1 r_2}{\sigma_1^2(1-\rho_1^2)}\right) + \\
& + P_2 \int_0^{r_T} \frac{r_{21} r_2}{\sigma_2^4(1-\rho_2^2)} e^{-\frac{r_{21}^2+r_2^2}{2\sigma_2^2(1-\rho_2^2)}} I_0\left(\frac{\rho_2 r_{21} r_2}{\sigma_2^2(1-\rho_2^2)}\right) dr_{21} \int_0^{r_T} \frac{r_{12} r_1}{\sigma_1^4(1-\rho_1^2)} e^{-\frac{r_{12}^2+r_1^2}{2\sigma_1^2(1-\rho_1^2)}} I_0\left(\frac{\rho_1 r_{12} r_1}{\sigma_1^2(1-\rho_1^2)}\right) dr_{12}
\end{aligned}
\tag{3.3.9}
$$

Izrazi (3.3.6-9) su u obliku jednostrukog integrala sa konačnim granicama. Združena gustina raspodele verovatnoće signala na izlazu iz SSC kombinera u dva vremenska trenutka se može dobiti u zatvorenom obliku korišćenjem Marcum-ove Q-funkcije prvog reda koja se definiše kao [1]:

$$
Q_1(\alpha, \beta) = \int_\beta^\infty x \exp\left[-\left(\frac{x^2+\alpha^2}{2}\right)\right] I_0(\alpha x) dx \tag{3.3.10}
$$

Za predstavljanje združene PDF u zatvorenom obliku potrebno je rešiti integral $\int_{r_T}^\infty p_{x_1 x_2}(x_1, x_2) dx_1$, gde je $p_{x_1 x_2}(x_1, x_2)$ dato u (3.3.5). Transformacijom $p_{x_1 x_2}(x_1, x_2)$, ona se može prikazati u obliku koji u podintegralnom delu predstavlja podintegralni deo Marcum-ove Q-funkcije prvog reda.

$$x_1 = x\sigma\sqrt{1-\rho^2} \qquad x = \frac{x_1}{\sigma\sqrt{1-\rho^2}} \tag{3.3.11}$$

$$x_2 = \frac{\alpha\sigma}{\rho}\sqrt{1-\rho^2} \qquad \alpha = \frac{\rho x_2}{\sigma\sqrt{1-\rho^2}} \tag{3.3.12}$$

$$p_{x_1x_2}(x_1,x_2) = \frac{\alpha}{\rho\sigma^2} e^{-\frac{1-\rho^2}{2\rho^2}\alpha^2} x e^{-\frac{x^2+\alpha^2}{2}} I_0(\alpha x) \tag{3.3.13}$$

$$\int_{r_T}^{\infty} p_{x_1x_2}(x_1,x_2)dx_1 = \frac{\alpha}{\rho\sigma^2} e^{-\frac{1-\rho^2}{2\rho^2}\alpha^2} \int_{r_T}^{\infty} x e^{-\frac{x^2+\alpha^2}{2}} I_0(\alpha x) dx_1 =$$

$$= \frac{\alpha}{\rho\sigma^2} e^{-\frac{1-\rho^2}{2\rho^2}\alpha^2} \int_{\frac{r_T}{\sigma\sqrt{1-\rho^2}}}^{\infty} x e^{-\frac{x^2+\alpha^2}{2}} I_0(\alpha x) dx\sigma\sqrt{1-\rho^2} = \frac{x_2}{\sigma^2} e^{-\frac{x_2^2}{2\sigma^2}} Q_1\left(\frac{\rho x_2}{\sigma\sqrt{1-\rho^2}}, \frac{r_T}{\sigma\sqrt{1-\rho^2}}\right) \tag{3.3.14}$$

Na osnovu (3.3.14) se dobija:

$$\int_{0}^{r_T} p_{x_1x_2}(x_1,x_2)dx_1 = \frac{x_2}{\sigma^2} e^{-\frac{x_2^2}{2\sigma^2}} \left[1 - Q_1\left(\frac{\rho x_2}{\sigma\sqrt{1-\rho^2}}, \frac{r_T}{\sigma\sqrt{1-\rho^2}}\right)\right] \tag{3.3.15}$$

Zamenom (3.3.15) u izrazima (3.3.6-9) dobija se konačni oblik za združenu gustinu raspodele verovatnoće na izlazu iz SSC kombinera

Za $r_1<r_T$, $r_2<r_T$

$$\begin{aligned} p_{r_1r_2}(r_1,r_2) = {} & P_1 \frac{r_1}{\sigma_2{}^2} e^{-\frac{r_1{}^2}{2\sigma_2{}^2}} \frac{r_2}{\sigma_1{}^2} e^{-\frac{r_2{}^2}{2\sigma_1{}^2}} \cdot \\ & \cdot \left[1 - Q_1\left(\frac{\rho_2 r_1}{\sigma_2\sqrt{1-\rho_2{}^2}}, \frac{r_T}{\sigma_2\sqrt{1-\rho_2{}^2}}\right)\right]\left[1 - Q_1\left(\frac{\rho_1 r_2}{\sigma_1\sqrt{1-\rho_1{}^2}}, \frac{r_T}{\sigma_1\sqrt{1-\rho_1{}^2}}\right)\right] + \\ & + P_2 \frac{r_1}{\sigma_1{}^2} e^{-\frac{r_1{}^2}{2\sigma_1{}^2}} \frac{r_2}{\sigma_2{}^2} e^{-\frac{r_2{}^2}{2\sigma_2{}^2}} \left[1 - Q_1\left(\frac{\rho_1 r_1}{\sigma_1\sqrt{1-\rho_1{}^2}}, \frac{r_T}{\sigma_1\sqrt{1-\rho_1{}^2}}\right)\right]\left[1 - Q_1\left(\frac{\rho_2 r_2}{\sigma_2\sqrt{1-\rho_2{}^2}}, \frac{r_T}{\sigma_2\sqrt{1-\rho_2{}^2}}\right)\right] \end{aligned} \tag{3.3.16}$$

Za $r_1 \geq r_T$, $r_2<r_T$

$$p_{r_1r_2}(r_1,r_2) = P_1 \frac{r_1}{\sigma_1{}^2} e^{-\frac{r_1{}^2}{2\sigma_1{}^2}} \frac{r_2}{\sigma_2{}^2} e^{-\frac{r_2{}^2}{2\sigma_2{}^2}} \left[1 - Q_1\left(\frac{\rho_1 r_1}{\sigma_1\sqrt{1-\rho_1{}^2}}, \frac{r_T}{\sigma_1\sqrt{1-\rho_1{}^2}}\right)\right] +$$

$$+P_1\frac{r_1}{\sigma_2{}^2}e^{-\frac{r_1{}^2}{2\sigma_2{}^2}}\frac{r_2}{\sigma_1{}^2}e^{-\frac{r_2{}^2}{2\sigma_1{}^2}}\left[1-Q_1\left(\frac{\rho_2 r_1}{\sigma_2\sqrt{1-\rho_2{}^2}},\frac{r_T}{\sigma_2\sqrt{1-\rho_2{}^2}}\right)\right]\left[1-Q_1\left(\frac{\rho_1 r_2}{\sigma_1\sqrt{1-\rho_1{}^2}},\frac{r_T}{\sigma_1\sqrt{1-\rho_1{}^2}}\right)\right]+$$

$$+P_2\frac{r_1}{\sigma_2{}^2}e^{-\frac{r_1{}^2}{2\sigma_2{}^2}}\frac{r_2}{\sigma_1{}^2}e^{-\frac{r_2{}^2}{2\sigma_1{}^2}}\left[1-Q_1\frac{\rho_2 r_1}{\sigma_2\sqrt{1-\rho_2{}^2}}\frac{r_T}{\sigma_2\sqrt{1-\rho_2{}^2}}\right]+$$

$$+P_2\frac{r_1}{\sigma_1{}^2}e^{-\frac{r_1{}^2}{2\sigma_1{}^2}}\frac{r_2}{\sigma_2{}^2}e^{-\frac{r_2{}^2}{2\sigma_2{}^2}}\left[1-Q_1\left(\frac{\rho_1 r_1}{\sigma_1\sqrt{1-\rho_1{}^2}},\frac{r_T}{\sigma_1\sqrt{1-\rho_1{}^2}}\right)\right]\left[1-Q_1\left(\frac{\rho_2 r_2}{\sigma_2\sqrt{1-\rho_2{}^2}},\frac{r_T}{\sigma_2\sqrt{1-\rho_2{}^2}}\right)\right]$$

(3.3.17)

Za $r_1<r_T$, $r_2\geq r_T$

$$p_{r_1r_2}(r_1,r_2)=P_1\left(1-e^{-\frac{r_T{}^2}{2\sigma_1{}^2}}\right)\frac{r_1r_2}{\sigma_2{}^4(1-\rho_2{}^2)}e^{-\frac{r_1{}^2+r_2{}^2}{2\sigma_2{}^2(1-\rho_2{}^2)}}I_0\left(\frac{\rho_2 r_1 r_2}{\sigma_2{}^2(1-\rho_2{}^2)}\right)+$$

$$+P_1\frac{r_1}{\sigma_2{}^2}e^{-\frac{r_1{}^2}{2\sigma_2{}^2}}\frac{r_2}{\sigma_1{}^2}e^{-\frac{r_2{}^2}{2\sigma_1{}^2}}\left[1-Q_1\left(\frac{\rho_2 r_1}{\sigma_2\sqrt{1-\rho_2{}^2}},\frac{r_T}{\sigma_2\sqrt{1-\rho_2{}^2}}\right)\right]\left[1-Q_1\left(\frac{\rho_1 r_2}{\sigma_1\sqrt{1-\rho_1{}^2}},\frac{r_T}{\sigma_1\sqrt{1-\rho_1{}^2}}\right)\right]+$$

$$+P_2\left(1-e^{-\frac{r_T{}^2}{2\sigma_2{}^2}}\right)\frac{r_1r_2}{\sigma_1{}^4(1-\rho_1{}^2)}e^{-\frac{r_1{}^2+r_2{}^2}{2\sigma_1{}^2(1-\rho_1{}^2)}}I_0\left(\frac{\rho_1 r_1 r_2}{\sigma_1{}^2(1-\rho_1{}^2)}\right)+$$

$$+P_2\frac{r_1}{\sigma_1{}^2}e^{-\frac{r_1{}^2}{2\sigma_1{}^2}}\frac{r_2}{\sigma_2{}^2}e^{-\frac{r_2{}^2}{2\sigma_2{}^2}}\left[1-Q_1\left(\frac{\rho_1 r_1}{\sigma_1\sqrt{1-\rho_1{}^2}},\frac{r_T}{\sigma_1\sqrt{1-\rho_1{}^2}}\right)\right]\left[1-Q_1\left(\frac{\rho_2 r_2}{\sigma_2\sqrt{1-\rho_2{}^2}},\frac{r_T}{\sigma_2\sqrt{1-\rho_2{}^2}}\right)\right]$$

(3.3.18)

Za $r_1\geq r_T$, $r_2\geq r_T$

$$p_{r_1r_2}(r_1,r_2)=P_1\frac{r_1r_2}{\sigma_1{}^4(1-\rho_1{}^2)}e^{-\frac{r_1{}^2+r_2{}^2}{2\sigma_1{}^2(1-\rho_1{}^2)}}I_0\left(\frac{\rho_1 r_1 r_2}{\sigma_1{}^2(1-\rho_1{}^2)}\right)+$$

$$+P_1\frac{r_1}{\sigma_1{}^2}e^{-\frac{r_1{}^2}{2\sigma_1{}^2}}\frac{r_2}{\sigma_2{}^2}e^{-\frac{r_2{}^2}{2\sigma_2{}^2}}\left[1-Q_1\left(\frac{\rho_1 r_1}{\sigma_1\sqrt{1-\rho_1{}^2}},\frac{r_T}{\sigma_1\sqrt{1-\rho_1{}^2}}\right)\right]+$$

$$+P_1\left(1-e^{-\frac{r_T{}^2}{2\sigma_1{}^2}}\right)\frac{r_1r_2}{\sigma_2{}^4(1-\rho^2)}e^{-\frac{r_1{}^2+r_2{}^2}{2\sigma_2{}^2(1-\rho^2)}}I_0\left(\frac{\rho r_1 r_2}{\sigma_2{}^2(1-\rho^2)}\right)+$$

$$+P_1\frac{r_1}{\sigma_2^2}e^{-\frac{r_1^2}{2\sigma_2^2}}\frac{r_2}{\sigma_1^2}e^{-\frac{r_2^2}{2\sigma_1^2}}\left[1-Q_1\left(\frac{\rho_2 r_1}{\sigma_2\sqrt{1-\rho_2^2}},\frac{r_T}{\sigma_2\sqrt{1-\rho_2^2}}\right)\right]\left[1-Q_1\left(\frac{\rho_1 r_2}{\sigma_1\sqrt{1-\rho_1^2}},\frac{r_T}{\sigma_1\sqrt{1-\rho_1^2}}\right)\right]+$$

$$+P_2\frac{r_1 r_2}{\sigma_2^4(1-\rho^2)}e^{-\frac{r_1^2+r_2^2}{2\sigma_2^2(1-\rho^2)}}I_0\left(\frac{\rho r_1 r_2}{\sigma_2^2(1-\rho^2)}\right)+$$

$$+P_2\frac{r_1}{\sigma_2^2}e^{-\frac{r_1^2}{2\sigma_2^2}}\frac{r_2}{\sigma_1^2}e^{-\frac{r_2^2}{2\sigma_1^2}}\left[1-Q_1\left(\frac{\rho_2 r_1}{\sigma_2\sqrt{1-\rho_2^2}},\frac{r_T}{\sigma_2\sqrt{1-\rho_2^2}}\right)\right]+$$

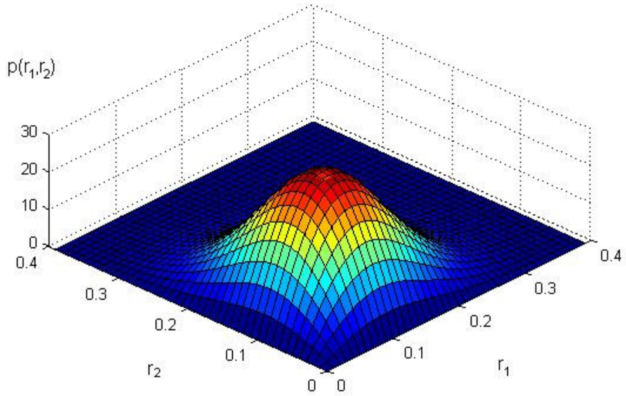
$$+P_2\left(1-e^{-\frac{r_T}{2\sigma_2^2}}\right)\frac{r_1 r_2}{\sigma_1^4(1-\rho^2)}e^{-\frac{r_1^2+r_2^2}{2\sigma_1^2(1-\rho^2)}}I_0\left(\frac{\rho r_1 r_2}{\sigma_1^2(1-\rho^2)}\right)+$$

$$+P_2\frac{r_1}{\sigma_1^2}e^{-\frac{r_1^2}{2\sigma_1^2}}\frac{r_2}{\sigma_2^2}e^{-\frac{r_2^2}{2\sigma_2^2}}\left[1-Q_1\left(\frac{\rho_1 r_1}{\sigma_1\sqrt{1-\rho_1^2}},\frac{r_T}{\sigma_1\sqrt{1-\rho_1^2}}\right)\right]\left[1-Q_1\left(\frac{\rho_2 r_2}{\sigma_2\sqrt{1-\rho_2^2}},\frac{r_T}{\sigma_2\sqrt{1-\rho_2^2}}\right)\right]$$

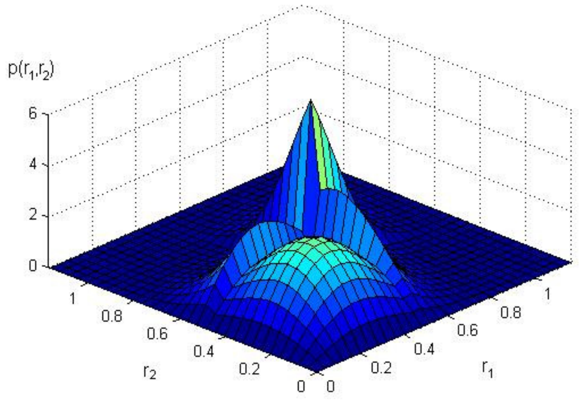
(3.3.19)

Združena gustina raspodele verovatnoće na izlazu iz SSC kombinera se može jednostavno predstaviti grafički upotrebom matematičkog softvera kao što je “MatLab”. Radi uproštavanja, a ne gubeći uopštenost, pretpostavljeno je da su parametri raspodele isti za obe grane kombinera.

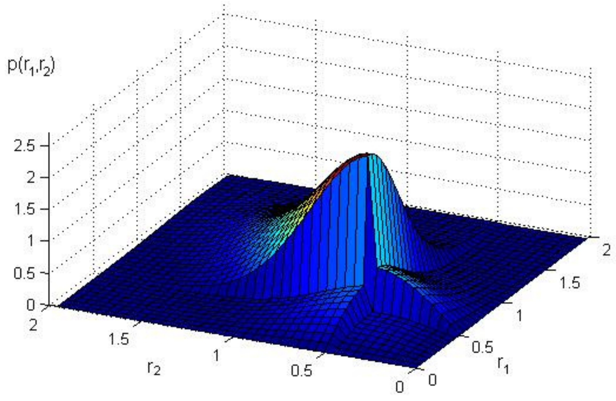
Na slikama 3.3.1.-9. predstavljena je zavisnost PDF na izlazu od vrednosti signala na ulazu za različite vrednosti standardne devijacije, korelacije i praga odlučivanja.



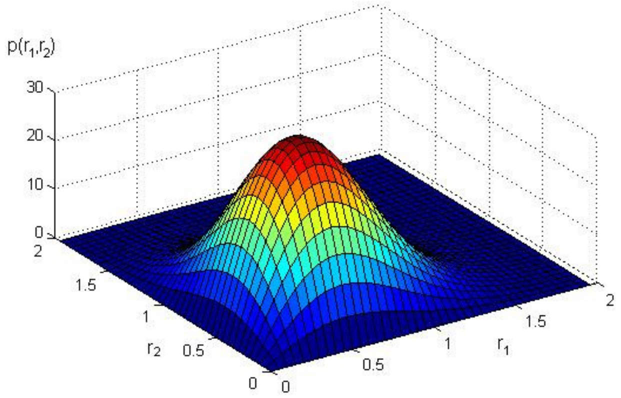
Slika 3.3.1. Združena gustina raspodele verovatnoće na izlazu iz SSC kombinera u dva trenutka vremena prisustvu Rayleigh-jevog fedinga za parametre: $\rho = 0.8$, $r_T = 0.5$, $\sigma = 0.1$



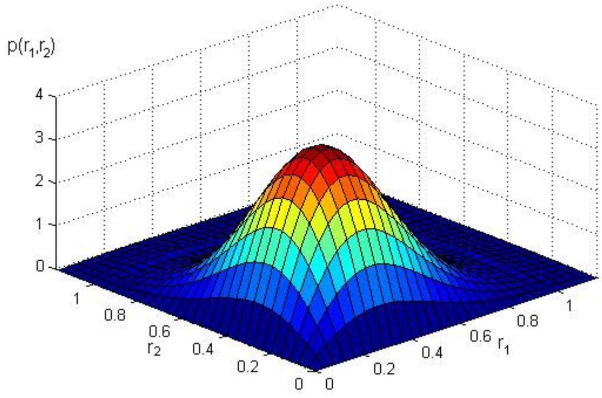
Slika 3.3.2. Združena gustina raspodele verovatnoće na izlazu iz SSC kombinera u dva trenutka vremena u prisustvu Rayleigh-jevog fedinga za parametre: $\rho = 0.8$, $r_T = 0.5$, $\sigma = 0.3$



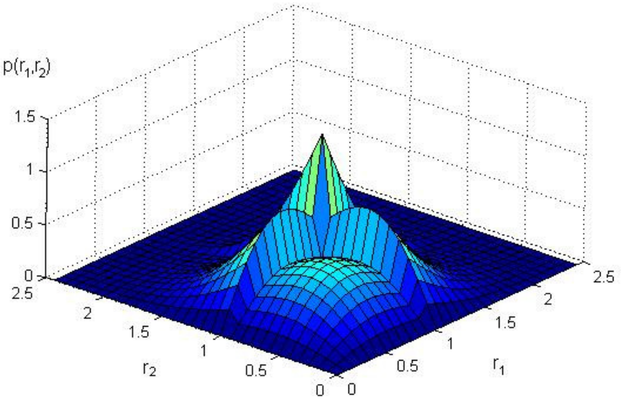
Slika 3.3.3. Združena gustina raspodele verovatnoće na izlazu iz SSC kombinera u dva trenutka vremena u prisustvu Rayleigh-jevog fedinga za parametre: $\rho = 0.8$, $r_T = 0.5$, $\sigma = 0.6$



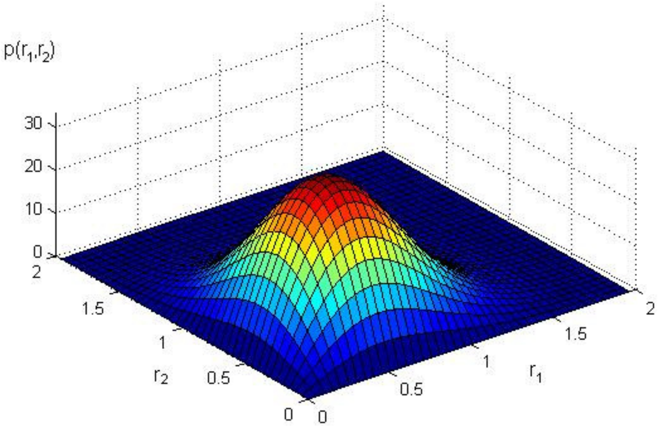
Slika 3.3.4. Združena gustina raspodele verovatnoće na izlazu iz SSC kombinera u dva trenutka vremena u prisustvu Rayleigh-jevog fedinga za parametre: $\rho = 0.1$, $r_T = 1$, $\sigma = 0.1$



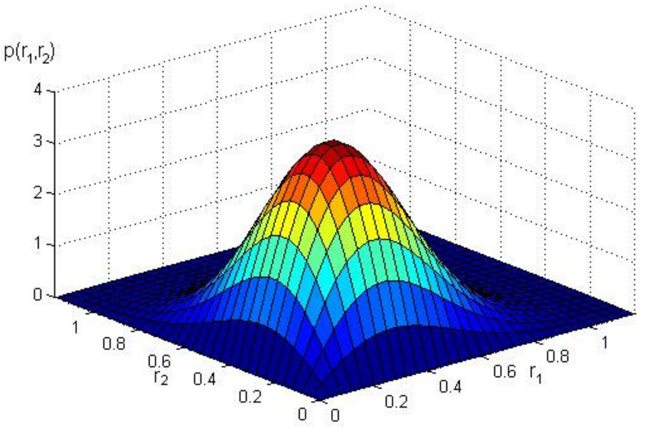
Slika 3.3.5. Združena gustina raspodele verovatnoće na izlazu iz SSC kombinera u dva trenutka vremena u prisustvu Rayleigh-jevog fedinga za parametre: $\rho = 0.1$, $r_T = 1$, $\sigma = 0.3$



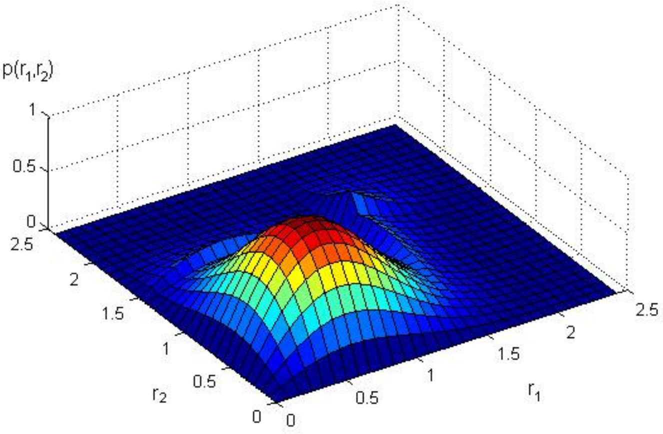
Slika 3.3.6. Združena gustina raspodele verovatnoće na izlazu iz SSC kombinera u dva trenutka vremena u prisustvu Rayleigh-jevog fedinga za parametre: $\rho = 0.1$, $r_T = 1$, $\sigma = 0.6$



Slika 3.3.7. Združena gustina raspodele verovatnoće na izlazu iz SSC kombinera u dva trenutka vremena u prisustvu Rayleigh-jevog fedinga za parametre: $\rho = 0.8$, $r_T = 1.5$, $\sigma = 0.1$



Slika 3.3.8. Združena gustina raspodele verovatnoće na izlazu iz SSC kombinera u dva trenutka vremena u prisustvu Rayleigh-jevog fedinga za parametre: $\rho = 0.8$, $r_T = 1.5$, $\sigma = 0.3$



Slika 3.3.9. Združena gustina raspodele verovatnoće na izlazu iz SSC kombinera u dva trenutka vremena u prisustvu Rayleigh-jevog fedinga za parametre: $\rho = 0.8$, $r_T = 1.5$, $\sigma = 0.6$

3.4 Združena gustina raspodele verovatnoće na izlazu SSC kombinera u dva trenutka vremena u prisustvu Nakagami-m fedinga

Gustina raspodele verovatnoće i kumulativna raspodela verovatnoće (CDF) signala na ulazima u grane kombinera $r_{i,j}$ u prisustvu Nakagami-m fedinga su [1]:

$$p_{r_i}(r_{i,j}) = \frac{2 m_i^{m_i} r_{i,j}^{2m_i - 1}}{\Omega_i^{m_i} \Gamma(m_i)} e^{-\frac{m_i r_{i,j}^2}{\Omega_i}} \quad , \quad r_{i,j} \geq 0 \qquad (3.4.1)$$

$$F_{r_i}(r_{i,j}) = \gamma\left(\frac{m_i}{\Omega_i} r_{i,j}{}^2, m_i\right) \qquad , \quad r_{i,j} \geq 0 \tag{3.4.2}$$

gde su *i=1,2 j=1,2*, *m* je Nakagami-m faktor, a Ω je srednja vrednost snage signala. $\gamma(x,a)$ je nekompletna gama funkcija definisana sa [45]:

$$\gamma(x,a) = \frac{1}{\Gamma(a)} \int_0^x t^{a-1} e^{-t} dt \tag{3.4.3}$$

Verovatnoće P_1 i P_2 se dobijaju ako se u (3.1.17-18) stavi (3.3.15):

$$P_1 = \frac{\gamma(\frac{m_2}{\Omega_2} r_t{}^2, m_2)}{\gamma(\frac{m_1}{\Omega_1} r_t{}^2, m_1) + \gamma(\frac{m_2}{\Omega_2} r_t{}^2, m_2)} \tag{3.4.4}$$

$$P_2 = \frac{\gamma(\frac{m_1}{\Omega_1} r_t{}^2, m_1)}{\gamma(\frac{m_1}{\Omega_1} r_t{}^2, m_1) + \gamma(\frac{m_2}{\Omega_2} r_t{}^2, m_2)} \tag{3.4.5}$$

Združena gustina raspodele verovatnoće korelisanih signala x_1 i x_2 sa Nakagami-m raspodelom i istim parametrima raspodele je [52], [53]:

$$p_{x_1x_2}(x_1,x_2) = \frac{4(x_1x_2)^m}{\Gamma(m)(1-\rho)\rho^{(m-1)/2}} \left(\frac{m}{\Omega}\right)^{m+1} \cdot I_{m-1}\left(\frac{2m\sqrt{\rho}\, x_1x_2}{\Omega(1-\rho)}\right) e^{-\frac{m\left(x_1^2+x_2^2\right)}{\Omega(1-\rho)}} \tag{3.4.6}$$

gde je ρ koeficijent korelacije, a $I_m(\ )$ je modifikovana Bessel-ova funkcija prve vrste m-tog reda [51]:

$$I_m(x) = \left(\frac{x}{2}\right)^m \sum_{k=0}^{\infty} \frac{\left(\frac{x^2}{4}\right)^k}{k!\Gamma(m+k+1)} \tag{3.4.7}$$

Združena gustina raspodele verovatnoće signala r_1 i r_2 na izlazu SSC kombinera u dva trenutka vremena u prisustvu Nakagami-m fedinga kada su signali na ulazu u grane kombinera nezavisni, može se dobiti ako se u (3.2.5-8) stave izrazi (3.4.1) i (3.4.5)

Za $r_1<r_T$, $r_2<r_T$

$$p_{r_1r_2}(r_1,r_2) = P_1 \int_0^{r_T} \frac{4(r_{11}r_2)^{m_1}}{\Gamma(m_1)(1-\rho_1)\rho_1^{(m_1-1)/2}} \left(\frac{m_1}{\Omega_1}\right)^{m_1+1} I_{m-1}\left(\frac{2m_1\sqrt{\rho_1}\, r_{11}r_2}{\Omega_1(1-\rho_1)}\right) e^{-\frac{m_1\left(r_{11}{}^2+r_2^2\right)}{\Omega_1(1-\rho_1)}} dr_{11} \cdot$$

$$\cdot\int_0^{r_T}\frac{4\left(r_{22}r_1\right)^{m_2}}{\Gamma(m_2)(1-\rho_2)\rho_2^{(m_2-1)/2}}\left(\frac{m_2}{\Omega_2}\right)^{m_2+1}I_{m-1}\left(\frac{2m_2\sqrt{\rho_2}\,r_{22}r_1}{\Omega_2(1-\rho_2)}\right)e^{-\frac{m_2\left(r_{22}^2+r_1^2\right)}{\Omega_2(1-\rho_2)}}dr_{22}+$$

$$+P_2\int_0^{r_T}\frac{4\left(r_{21}r_2\right)^{m_2}}{\Gamma(m_2)(1-\rho_2)\rho_2^{(m_2-1)/2}}\left(\frac{m_2}{\Omega_2}\right)^{m_2+1}I_{m-1}\left(\frac{2m_2\sqrt{\rho_2}\,r_{21}r_2}{\Omega_2(1-\rho_2)}\right)e^{-\frac{m_2\left(r_{21}^2+r_2^2\right)}{\Omega_2(1-\rho_2)}}dr_{21}\cdot$$

$$\cdot\int_0^{r_T}\frac{4\left(r_{12}r_1\right)^{m_1}}{\Gamma(m_1)(1-\rho_1)\rho_1^{(m_1-1)/2}}\left(\frac{m_1}{\Omega_1}\right)^{m_1+1}I_{m-1}\left(\frac{2m_1\sqrt{\rho_1}\,r_{12}r_1}{\Omega_1(1-\rho_1)}\right)e^{-\frac{m_1\left(r_{12}^2+r_1^2\right)}{\Omega_1(1-\rho_1)}}dr_{12}\qquad(3.4.8)$$

Za $r_1 \geq r_T$, $r_2 < r_T$

$$p_{r_1r_2}(r_1,r_2)=P_1\frac{2m_2^{m_2}r_2^{2m_2-1}}{\Omega_2^{m_2}\Gamma(m_2)}e^{-\frac{m_2r_2^2}{\Omega_2}}\cdot$$

$$\cdot\int_0^{r_T}\frac{4\left(r_{12}r_1\right)^{m_1}}{\Gamma(m_1)(1-\rho_1)\rho_1^{(m_1-1)/2}}\left(\frac{m_1}{\Omega_1}\right)^{m_1+1}I_{m-1}\left(\frac{2m_1\sqrt{\rho_1}\,r_{12}r_1}{\Omega_1(1-\rho_1)}\right)e^{-\frac{m_1\left(r_{12}^2+r_1^2\right)}{\Omega_1(1-\rho_1)}}dr_{12}+$$

$$+P_1\int_0^{r_T}\frac{4\left(r_{11}r_2\right)^{m_1}}{\Gamma(m_1)(1-\rho_1)\rho_1^{(m_1-1)/2}}\left(\frac{m_1}{\Omega_1}\right)^{m_1+1}I_{m-1}\left(\frac{2m_1\sqrt{\rho_1}\,r_{11}r_2}{\Omega_1(1-\rho_1)}\right)e^{-\frac{m_1\left(r_{11}^2+r_2^2\right)}{\Omega_1(1-\rho_1)}}dr_{11}\cdot$$

$$\cdot\int_0^{r_T}\frac{4\left(r_{22}r_1\right)^{m_2}}{\Gamma(m_2)(1-\rho_2)\rho_2^{(m_2-1)/2}}\left(\frac{m_2}{\Omega_2}\right)^{m_2+1}I_{m-1}\left(\frac{2m_2\sqrt{\rho_2}\,r_{22}r_1}{\Omega_2(1-\rho_2)}\right)e^{-\frac{m_2\left(r_{22}^2+r_1^2\right)}{\Omega_2(1-\rho_2)}}dr_{22}+$$

$$+P_2\frac{2m_1^{m_1}r_2^{2m_1-1}}{\Omega_1^{m_1}\Gamma(m_1)}e^{-\frac{m_1r_2^2}{\Omega_1}}\int_0^{r_T}\frac{4\left(r_{22}r_1\right)^{m_2}}{\Gamma(m_2)(1-\rho_2)\rho_2^{(m_2-1)/2}}\left(\frac{m_2}{\Omega_2}\right)^{m_2+1}I_{m-1}\left(\frac{2m_2\sqrt{\rho_2}\,r_{22}r_1}{\Omega_2(1-\rho_2)}\right)e^{-\frac{m_2\left(r_{22}^2+r_1^2\right)}{\Omega_2(1-\rho_2)}}dr_{22}+$$

$$+P_2\int_0^{r_T}\frac{4\left(r_{21}r_2\right)^{m_2}}{\Gamma(m_2)(1-\rho_2)\rho_2^{(m_2-1)/2}}\left(\frac{m_2}{\Omega_2}\right)^{m_2+1}I_{m-1}\left(\frac{2m_2\sqrt{\rho_2}\,r_{21}r_2}{\Omega_2(1-\rho_2)}\right)e^{-\frac{m_2\left(r_{21}^2+r_2^2\right)}{\Omega_2(1-\rho_2)}}dr_{21}\cdot$$

$$\cdot\int_0^{r_T}\frac{4\left(r_{12}r_1\right)^{m_1}}{\Gamma(m_1)(1-\rho_1)\rho_1^{(m_1-1)/2}}\left(\frac{m_1}{\Omega_1}\right)^{m_1+1}I_{m-1}\left(\frac{2m_1\sqrt{\rho_1}\,r_{12}r_1}{\Omega_1(1-\rho_1)}\right)e^{-\frac{m_1\left(r_{12}^2+r_1^2\right)}{\Omega_1(1-\rho_1)}}dr_{12}\qquad(3.4.9)$$

Za $r_1 < r_T$, $r_2 \geq r_T$

$$p_{r_1r_2}(r_1,r_2)=P_1\gamma\left(\frac{m_1}{\Omega_1}r_T^2,m_1\right)\frac{4\left(r_1r_2\right)^{m_2}}{\Gamma(m_2)(1-\rho_2)\rho_2^{(m_2-1)/2}}\left(\frac{m_2}{\Omega_2}\right)^{m_2+1}I_{m-1}\left(\frac{2m_2\sqrt{\rho_2}\,r_1r_2}{\Omega_2(1-\rho_2)}\right)e^{-\frac{m_2\left(r_1^2+r_2^2\right)}{\Omega_2(1-\rho_2)}}+$$

$$+P_1\int_0^{r_T}\frac{4\left(r_{11}r_2\right)^{m_1}}{\Gamma(m_1)(1-\rho_1)\rho_1^{(m_1-1)/2}}\left(\frac{m_1}{\Omega_1}\right)^{m_1+1}I_{m-1}\left(\frac{2m_1\sqrt{\rho_1}\,r_{11}r_2}{\Omega_1(1-\rho_1)}\right)e^{-\frac{m_1\left(r_{11}^2+r_2^2\right)}{\Omega_1(1-\rho_1)}}dr_{11}\cdot$$

$$\cdot\int_0^{r_T}\frac{4\left(r_{22}r_1\right)^{m_2}}{\Gamma(m_2)(1-\rho_2)\rho_2^{(m_2-1)/2}}\left(\frac{m_2}{\Omega_2}\right)^{m_2+1}I_{m-1}\left(\frac{2m_2\sqrt{\rho_2}\,r_{22}r_1}{\Omega_2(1-\rho_2)}\right)e^{-\frac{m_2\left(r_{22}^2+r_1^2\right)}{\Omega_2(1-\rho_2)}}dr_{22}+$$

$$+P_2\gamma\left(\frac{m_2}{\Omega_2}r_T^{\ 2},m_2\right)\cdot\frac{4\left(r_1r_2\right)^{m_1}}{\Gamma\left(m_1\right)\left(1-\rho_1\right)\rho_1^{\ (m_1-1)/2}}\left(\frac{m_1}{\Omega_1}\right)^{m_1+1}I_{m-1}\left(\frac{2m_1\sqrt{\rho_1}\ r_1r_2}{\Omega_1\left(1-\rho_1\right)}\right)e^{-\frac{m_1\left(r_1^{\ 2}+r_2^2\right)}{\Omega_1(1-\rho_1)}}+$$

$$+P_2\int_0^{r_T}\frac{4\left(r_{21}r_2\right)^{m_2}}{\Gamma\left(m_2\right)\left(1-\rho_2\right)\rho_2^{\ (m_2-1)/2}}\left(\frac{m_2}{\Omega_2}\right)^{m_2+1}I_{m-1}\left(\frac{2m_2\sqrt{\rho_2}\ r_{21}r_2}{\Omega_2\left(1-\rho_2\right)}\right)e^{-\frac{m_2\left(r_{21}^{\ 2}+r_2^2\right)}{\Omega_2(1-\rho_2)}}dr_{21}\cdot$$

$$\cdot\int_0^{r_T}\frac{4\left(r_{12}r_1\right)^{m_1}}{\Gamma\left(m_1\right)\left(1-\rho_1\right)\rho_1^{\ (m_1-1)/2}}\left(\frac{m_1}{\Omega_1}\right)^{m_1+1}I_{m-1}\left(\frac{2m_1\sqrt{\rho_1}\ r_{12}r_1}{\Omega_1\left(1-\rho_1\right)}\right)e^{-\frac{m_1\left(r_{12}^{\ 2}+r_1^2\right)}{\Omega_1(1-\rho_1)}}dr_{12}\qquad(3.4.10)$$

Za $r_1\geq r_T$, $r_2\geq r_T$

$$p_{r_1r_2}(r_1,r_2)=P_1\frac{4\left(r_1r_2\right)^{m_1}}{\Gamma\left(m_1\right)\left(1-\rho_1\right)\rho_1^{\ (m_1-1)/2}}\left(\frac{m_1}{\Omega_1}\right)^{m_1+1}I_{m-1}\left(\frac{2m_1\sqrt{\rho_1}\ r_1r_2}{\Omega_1\left(1-\rho_1\right)}\right)e^{-\frac{m_1\left(r_1^2+r_2^2\right)}{\Omega_1(1-\rho_1)}}+$$

$$+P_1\frac{2m_2^{\ m_2}r_2^{\ 2m_2-1}}{\Omega_2^{\ m_2}\Gamma\left(m_2\right)}e^{-\frac{m_2r_2^{\ 2}}{\Omega_2}}\int_0^{r_T}\frac{4\left(r_{12}r_1\right)^{m_1}}{\Gamma\left(m_1\right)\left(1-\rho_1\right)\rho_1^{\ (m_1-1)/2}}\left(\frac{m_1}{\Omega_1}\right)^{m_1+1}I_{m-1}\left(\frac{2m_1\sqrt{\rho_1}\ r_{12}r_1}{\Omega_1\left(1-\rho_1\right)}\right)e^{-\frac{m_1\left(r_{12}^{\ 2}+r_1^2\right)}{\Omega_1(1-\rho_1)}}dr_{12}+$$

$$+P_1\gamma\left(\frac{m_1}{\Omega_1}r_T^{\ 2},m_1\right)\frac{4\left(r_1r_2\right)^{m_2}}{\Gamma\left(m_2\right)\left(1-\rho_2\right)\rho_2^{\ (m_2-1)/2}}\left(\frac{m_2}{\Omega_2}\right)^{m_2+1}I_{m-1}\left(\frac{2m_2\sqrt{\rho_2}\ r_1r_2}{\Omega_2\left(1-\rho_2\right)}\right)e^{-\frac{m_2\left(r_1^{\ 2}+r_2^2\right)}{\Omega_2(1-\rho_2)}}+$$

$$+P_1\int_0^{r_T}\frac{4\left(r_{11}r_2\right)^{m_1}}{\Gamma\left(m_1\right)\left(1-\rho_1\right)\rho_1^{\ (m_1-1)/2}}\left(\frac{m_1}{\Omega_1}\right)^{m_1+1}I_{m-1}\left(\frac{2m_1\sqrt{\rho_1}\ r_{11}r_2}{\Omega_1\left(1-\rho_1\right)}\right)e^{-\frac{m_1\left(r_{11}^{\ 2}+r_2^2\right)}{\Omega_1(1-\rho_1)}}dr_{11}\cdot$$

$$\cdot\int_0^{r_T}\frac{4\left(r_{22}r_1\right)^{m_2}}{\Gamma\left(m_2\right)\left(1-\rho_2\right)\rho_2^{\ (m_2-1)/2}}\left(\frac{m_2}{\Omega_2}\right)^{m_2+1}I_{m-1}\left(\frac{2m_2\sqrt{\rho_2}\ r_{22}r_1}{\Omega_2\left(1-\rho_2\right)}\right)e^{-\frac{m_2\left(r_{22}^{\ 2}+r_1^2\right)}{\Omega_2(1-\rho_2)}}dr_{22}+$$

$$+P_2\frac{4\left(r_1r_2\right)^{m_2}}{\Gamma\left(m_2\right)\left(1-\rho_2\right)\rho_2^{\ (m_2-1)/2}}\left(\frac{m_2}{\Omega_2}\right)^{m_2+1}I_{m-1}\left(\frac{2m_2\sqrt{\rho_2}\ r_1r_2}{\Omega_2\left(1-\rho_2\right)}\right)e^{-\frac{m_2\left(r_1^2+r_2^2\right)}{\Omega_2(1-\rho_2)}}+$$

$$+P_2\frac{2m_1^{\ m_1}r_2^{\ 2m_1-1}}{\Omega_1^{\ m_1}\Gamma\left(m_1\right)}e^{-\frac{m_1r_2^{\ 2}}{\Omega_1}}\int_0^{r_T}\frac{4\left(r_{22}r_1\right)^{m_2}}{\Gamma\left(m_2\right)\left(1-\rho_2\right)\rho_2^{\ (m_2-1)/2}}\left(\frac{m_2}{\Omega_2}\right)^{m_2+1}I_{m-1}\left(\frac{2m_2\sqrt{\rho_2}\ r_{22}r_1}{\Omega_2\left(1-\rho_2\right)}\right)e^{-\frac{m_2\left(r_{22}^{\ 2}+r_1^2\right)}{\Omega_2(1-\rho_2)}}dr_{22}+$$

$$+P_2\gamma\left(\frac{m_2}{\Omega_2}r_T^{\ 2},m_2\right)\cdot\frac{4\left(r_1r_2\right)^{m_1}}{\Gamma\left(m_1\right)\left(1-\rho_1\right)\rho_1^{\ (m_1-1)/2}}\left(\frac{m_1}{\Omega_1}\right)^{m_1+1}I_{m-1}\left(\frac{2m_1\sqrt{\rho_1}\ r_1r_2}{\Omega_1\left(1-\rho_1\right)}\right)e^{-\frac{m_1\left(r_1^{\ 2}+r_2^2\right)}{\Omega_1(1-\rho_1)}}+$$

$$+P_2\int_0^{r_T}\frac{4\left(r_{21}r_2\right)^{m_2}}{\Gamma\left(m_2\right)\left(1-\rho_2\right)\rho_2^{\ (m_2-1)/2}}\left(\frac{m_2}{\Omega_2}\right)^{m_2+1}I_{m-1}\left(\frac{2m_2\sqrt{\rho_2}\ r_{21}r_2}{\Omega_2\left(1-\rho_2\right)}\right)e^{-\frac{m_2\left(r_{21}^{\ 2}+r_2^2\right)}{\Omega_2(1-\rho_2)}}dr_{21}\cdot$$

$$\cdot\int_0^{r_T}\frac{4\left(r_{12}r_1\right)^{m_1}}{\Gamma\left(m_1\right)\left(1-\rho_1\right)\rho_1^{\ (m_1-1)/2}}\left(\frac{m_1}{\Omega_1}\right)^{m_1+1}I_{m-1}\left(\frac{2m_1\sqrt{\rho_1}\ r_{12}r_1}{\Omega_1\left(1-\rho_1\right)}\right)e^{-\frac{m_1\left(r_{12}^{\ 2}+r_1^2\right)}{\Omega_1(1-\rho_1)}}dr_{12}\qquad(3.4.11)$$

Izrazi (3.4.8-11) su u obliku jednostrukog integrala sa konačnim granicama. Združena gustina raspodele verovatnoće se može dobiti u zatvorenom obliku korišćenjem generalizovane Marcum-ove Q-funkcije (m-tog reda) definisane sa [1], [54]:

$$Q_m(\alpha,\beta)=\frac{1}{\alpha^{m-1}}\int_{\beta}^{\infty}x^m\exp\left[-\left(\frac{x^2+\alpha^2}{2}\right)\right]I_{m-1}(\alpha x)dx \tag{3.4.12}$$

gde je m ceo broj.

Združena gustina raspodele verovatnoće se može dobiti u zatvorenom obliku korišćenjem generalizovane Marcum-ove Q-funkcije m-tog reda, gde je m pozitivan ceo broj, što nije ozbiljno ograničenje, jer ako m nije ceo broj, ova formula se može upotrebiti za $\lfloor m\rfloor$ i $\lfloor m+1\rfloor$ za dobijanje donje i gornje granice.

Za predstavljanje združene PDF u zatvorenom obliku potrebno je rešiti integral $\int_{r_T}^{\infty}p_{x_1x_2}(x_1,x_2)dx_1$, gde je $p_{x_1x_2}(x_1,x_2)$ dato u (3.3.19). Transformacijom $p_{x_1x_2}(x_1,x_2)$, ona se može predstaviti u obliku koji u podintegralnom delu predstavlja podintegralni deo generalizovane Marcum-ove Q-funkcije m-tog reda.

$$x_1=x\frac{1}{\sqrt{2m}}\sqrt{\Omega(1-\rho)} \qquad x=\sqrt{2m}\frac{x_1}{\sqrt{\Omega(1-\rho)}} \tag{3.4.13}$$

$$x_2=\frac{\alpha}{\sqrt{2m\rho}}\sqrt{\Omega(1-\rho)} \qquad \alpha=\frac{\sqrt{2m\rho}x_2}{\sqrt{\Omega(1-\rho)}} \tag{3.4.14}$$

$$\begin{aligned}\int_{r_T}^{\infty}p_{x_1x_2}(x_1,x_2)dx_1&=\frac{4m\alpha^{2m-1}(1-\rho)^{m-1}}{2^m\Omega\Gamma(m)\rho^{m-1/2}}e^{-\frac{\alpha^2(1-\rho)}{2\rho}}\int_{r_T}^{\infty}\frac{1}{\alpha^{m-1}}x^m e^{-\frac{x^2+\alpha^2}{2}}I_{m-1}(x\alpha)dx_1=\\&=\frac{4m\alpha^{2m-1}(1-\rho)^{m-1}}{2^m\Omega\Gamma(m)\rho^{m-1/2}}e^{-\frac{\alpha^2(1-\rho)}{2\rho}}\int_{\sqrt{m}\sqrt{2}\frac{r_t}{\sqrt{\Omega}\sqrt{1-\rho}}}^{\infty}\frac{1}{\alpha^{m-1}}x^m e^{-\frac{x^2+\alpha^2}{2}}I_{m-1}(x\alpha)dx\frac{1}{\sqrt{2}\sqrt{m}}\sqrt{\Omega}\sqrt{1-\rho}=\\&=\frac{2m^m{x_2}^{2m-1}}{\Omega^m\Gamma(m)}e^{-\frac{m{x_2}^2}{\Omega}}Q_m\left(\frac{\sqrt{2m\rho}x_2}{\sqrt{\Omega(1-\rho)}},\frac{\sqrt{2m}r_t}{\sqrt{\Omega(1-\rho)}}\right)\end{aligned} \tag{3.4.15}$$

Na osnovu (3.4.15) se dobija:

$$\int_0^{r_T}p_{x_1x_2}(x_1,x_2)dx_1=\frac{2m^m{x_2}^{2m-1}}{\Omega^m\Gamma(m)}e^{-\frac{m{x_2}^2}{\Omega}}\left[1-Q_m\left(\frac{\sqrt{2m\rho}x_2}{\sqrt{\Omega(1-\rho)}},\frac{\sqrt{2m}r_T}{\sqrt{\Omega(1-\rho)}}\right)\right] \tag{3.4.16}$$

Zamenom (3.4.16) u izrazima (3.4.8-11) dobija se konačni oblik za združenu gustinu raspodele verovatnoće na izlazu iz SSC kombinera u prisustvu Nakagami-m fedinga koji je dobijen u zatvorenom obliku.

Za $r_1<r_T$, $r_2<r_T$

$$p_{r_1 r_2}(r_1,r_2)=P_1\frac{2m_2^{\,m_2}r_1^{\,2m_2-1}}{\Omega_2^{\,m_2}\Gamma(m_2)}e^{-\frac{m_2 r_1^{\,2}}{\Omega_2}}\frac{2m_1^{\,m_1}r_2^{\,2m_1-1}}{\Omega_1^{\,m_1}\Gamma(m_1)}e^{-\frac{m_1 r_2^{\,2}}{\Omega_1}}\cdot$$

$$\cdot\left[1-Q_{m_2}\left(\frac{\sqrt{2m_2\rho_1}r_1}{\sqrt{\Omega_2(1-\rho_1)}},\frac{\sqrt{2m_2}r_T}{\sqrt{\Omega_2(1-\rho_1)}}\right)\right]\left[1-Q_{m_1}\left(\frac{\sqrt{2m_1\rho_1}r_2}{\sqrt{\Omega_1(1-\rho_1)}},\frac{\sqrt{2m_1}r_T}{\sqrt{\Omega_1(1-\rho_1)}}\right)\right]+$$

$$+P_2\frac{2m_1^{\,m_1}r_1^{\,2m_1-1}}{\Omega_1^{\,m_1}\Gamma(m_1)}e^{-\frac{m_1 r_1^{\,2}}{\Omega_1}}\frac{2m_2^{\,m_2}r_2^{\,2m_2-1}}{\Omega_2^{\,m_2}\Gamma(m_2)}e^{-\frac{m_2 r_2^{\,2}}{\Omega_2}}\cdot$$

$$\cdot\left[1-Q_{m_1}\left(\frac{\sqrt{2m_1\rho_1}r_1}{\sqrt{\Omega_1(1-\rho_1)}},\frac{\sqrt{2m_1}r_t}{\sqrt{\Omega_1(1-\rho_1)}}\right)\right]\left[1-Q_{m_2}\left(\frac{\sqrt{2m_2\rho_2}r_2}{\sqrt{\Omega_2(1-\rho_2)}},\frac{\sqrt{2m_2}r_t}{\sqrt{\Omega_2(1-\rho_2)}}\right)\right] \qquad (3.4.17)$$

Za $r_1\geq r_T$, $r_2<r_T$

$$p_{r_1 r_2}(r_1,r_2)=P_1\frac{2m_1^{\,m_1}r_1^{\,2m_1-1}}{\Omega_1^{\,m_1}\Gamma(m_1)}e^{-\frac{m_1 r_1^{\,2}}{\Omega_1}}\frac{2m_2^{\,m_2}r_2^{\,2m_2-1}}{\Omega_2^{\,m_2}\Gamma(m_2)}e^{-\frac{m_2 r_2^{\,2}}{\Omega_2}}\left[1-Q_{m_1}\left(\frac{\sqrt{2m_1\rho_1}r_1}{\sqrt{\Omega_1(1-\rho_1)}},\frac{\sqrt{2m_1}r_t}{\sqrt{\Omega_1(1-\rho_1)}}\right)\right]+$$

$$+P_1\frac{2m_2^{\,m_2}r_1^{\,2m_2-1}}{\Omega_2^{\,m_2}\Gamma(m_2)}e^{-\frac{m_2 r_1^{\,2}}{\Omega_2}}\frac{2m_1^{\,m_1}r_2^{\,2m_1-1}}{\Omega_1^{\,m_1}\Gamma(m_1)}e^{-\frac{m_1 r_2^{\,2}}{\Omega_1}}\cdot$$

$$\cdot\left[1-Q_{m_2}\left(\frac{\sqrt{2m_2\rho_1}r_1}{\sqrt{\Omega_2(1-\rho_1)}},\frac{\sqrt{2m_2}r_T}{\sqrt{\Omega_2(1-\rho_1)}}\right)\right]\left[1-Q_{m_1}\left(\frac{\sqrt{2m_1\rho_1}r_2}{\sqrt{\Omega_1(1-\rho_1)}},\frac{\sqrt{2m_1}r_T}{\sqrt{\Omega_1(1-\rho_1)}}\right)\right]+$$

$$+P_2\frac{2m_2^{\,m_2}r_1^{\,2m_2-1}}{\Omega_2^{\,m_2}\Gamma(m_2)}e^{-\frac{m_2 r_1^{\,2}}{\Omega_2}}\frac{2m_1^{\,m_1}r_2^{\,2m_1-1}}{\Omega_1^{\,m_1}\Gamma(m_1)}e^{-\frac{m_1 r_2^{\,2}}{\Omega_1}}\left[1-Q_{m_2}\left(\frac{\sqrt{2m_2\rho_2}r_1}{\sqrt{\Omega_2(1-\rho_2)}},\frac{\sqrt{2m_2}r_t}{\sqrt{\Omega_2(1-\rho_2)}}\right)\right]+$$

$$+P_2\frac{2m_1^{\,m_1}r_1^{\,2m_1-1}}{\Omega_1^{\,m_1}\Gamma(m_1)}e^{-\frac{m_1 r_1^{\,2}}{\Omega_1}}\frac{2m_2^{\,m_2}r_2^{\,2m_2-1}}{\Omega_2^{\,m_2}\Gamma(m_2)}e^{-\frac{m_2 r_2^{\,2}}{\Omega_2}}\cdot$$

$$\cdot\left[1-Q_{m_1}\left(\frac{\sqrt{2m_1\rho_1}r_1}{\sqrt{\Omega_1(1-\rho_1)}},\frac{\sqrt{2m_1}r_t}{\sqrt{\Omega_1(1-\rho_1)}}\right)\right]\left[1-Q_{m_2}\left(\frac{\sqrt{2m_2\rho_2}r_2}{\sqrt{\Omega_2(1-\rho_2)}},\frac{\sqrt{2m_2}r_t}{\sqrt{\Omega_2(1-\rho_2)}}\right)\right] \qquad (3.4.18)$$

Za $r_1<r_T$, $r_2\geq r_T$

$$p_{r_1 r_2}(r_1,r_2)=P_1\gamma\left(\frac{m_1}{\Omega_1}r_T^{\,2},m_1\right)\frac{4(r_1 r_2)^{m_2}}{\Gamma(m_2)(1-\rho_2)\rho_2^{\,(m_2-1)/2}}\left(\frac{m_2}{\Omega_2}\right)^{m_2+1}I_{m_2-1}\left(\frac{2m_2\sqrt{\rho_2}\,r_1 r_2}{\Omega_2(1-\rho_2)}\right)e^{-\frac{m_2\left(r_1^{\,2}+r_2^2\right)}{\Omega_2(1-\rho_2)}}+$$

$$+P_1\frac{2m_2^{\;m_2}r_1^{\;2m_2-1}}{\Omega_2^{\;m_2}\Gamma(m_2)}e^{-\frac{m_2r_1^{\;2}}{\Omega_2}}\frac{2m_1^{\;m_1}r_2^{\;2m_1-1}}{\Omega_1^{\;m_1}\Gamma(m_1)}e^{-\frac{m_1r_2^{\;2}}{\Omega_1}}\cdot$$

$$\cdot\left[1-Q_{m_2}\left(\frac{\sqrt{2m_2\rho_1}r_1}{\sqrt{\Omega_2(1-\rho_1)}},\frac{\sqrt{2m_2}r_T}{\sqrt{\Omega_2(1-\rho_1)}}\right)\right]\left[1-Q_{m_1}\left(\frac{\sqrt{2m_1\rho_1}r_2}{\sqrt{\Omega_1(1-\rho_1)}},\frac{\sqrt{2m_1}r_T}{\sqrt{\Omega_1(1-\rho_1)}}\right)\right]+$$

$$+P_2\gamma\left(\frac{m_2}{\Omega_2}r_T^{\;2},m_2\right)\cdot\frac{4(r_1r_2)^{m_1}}{\Gamma(m_1)(1-\rho_1)\rho_1^{\;(m_1-1)/2}}\left(\frac{m_1}{\Omega_1}\right)^{m_1+1}I_{m_1-1}\left(\frac{2m_1\sqrt{\rho_1}\,r_1r_2}{\Omega_1(1-\rho_1)}\right)e^{-\frac{m_1\left(r_1^{\;2}+r_2^2\right)}{\Omega_1(1-\rho_1)}}+$$

$$+P_2\frac{2m_1^{\;m_1}r_1^{\;2m_1-1}}{\Omega_1^{\;m_1}\Gamma(m_1)}e^{-\frac{m_1r_1^{\;2}}{\Omega_1}}\frac{2m_2^{\;m_2}r_2^{\;2m_2-1}}{\Omega_2^{\;m_2}\Gamma(m_2)}e^{-\frac{m_2r_2^{\;2}}{\Omega_2}}\cdot$$

$$\cdot\left[1-Q_{m_1}\left(\frac{\sqrt{2m_1\rho_1}r_1}{\sqrt{\Omega_1(1-\rho_1)}},\frac{\sqrt{2m_1}r_t}{\sqrt{\Omega_1(1-\rho_1)}}\right)\right]\left[1-Q_{m_2}\left(\frac{\sqrt{2m_2\rho_2}r_2}{\sqrt{\Omega_2(1-\rho_2)}},\frac{\sqrt{2m_2}r_t}{\sqrt{\Omega_2(1-\rho_{\,2})}}\right)\right]\qquad(3.4.19)$$

Za $r_1 \geq r_T$, $r_2 \geq r_T$

$$p_{r_1r_2}(r_1,r_2)=P_1\frac{4(r_1r_2)^{m_1}}{\Gamma(m_1)(1-\rho_1)\rho_1^{\;(m_1-1)/2}}\left(\frac{m_1}{\Omega_1}\right)^{m_1+1}I_{m_1-1}\left(\frac{2m_1\sqrt{\rho_1}\,r_1r_2}{\Omega_1(1-\rho_1)}\right)e^{-\frac{m_1\left(r_1^{\;2}+r_2^2\right)}{\Omega_1(1-\rho_1)}}+$$

$$+P_1\frac{2m_1^{\;m_1}r_1^{\;2m_1-1}}{\Omega_1^{\;m_1}\Gamma(m_1)}e^{-\frac{m_1r_1^{\;2}}{\Omega_1}}\frac{2m_2^{\;m_2}r_2^{\;2m_2-1}}{\Omega_2^{\;m_2}\Gamma(m_2)}e^{-\frac{m_2r_2^{\;2}}{\Omega_2}}\left[1-Q_{m_1}\left(\frac{\sqrt{2m_1\rho_1}r_1}{\sqrt{\Omega_1(1-\rho_1)}},\frac{\sqrt{2m_1}r_t}{\sqrt{\Omega_1(1-\rho_1)}}\right)\right]+$$

$$+P_1\gamma\left(\frac{m_1}{\Omega_1}r_T^{\;2},m_1\right)\frac{4(r_1r_2)^{m_2}}{\Gamma(m_2)(1-\rho)\rho_2^{\;(m_2-1)/2}}\left(\frac{m_2}{\Omega_2}\right)^{m_2+1}I_{m_2-1}\left(\frac{2m_2\sqrt{\rho_2}\,r_1r_2}{\Omega_2(1-\rho_2)}\right)e^{-\frac{m_2\left(r_1^{\;2}+r_2^2\right)}{\Omega_2(1-\rho_2)}}$$

$$+P_1\frac{2m_2^{\;m_2}r_1^{\;2m_2-1}}{\Omega_2^{\;m_2}\Gamma(m_2)}e^{-\frac{m_2r_1^{\;2}}{\Omega_2}}\frac{2m_1^{\;m_1}r_2^{\;2m_1-1}}{\Omega_1^{\;m_1}\Gamma(m_1)}e^{-\frac{m_1r_2^{\;2}}{\Omega_1}}\cdot$$

$$\cdot\left[1-Q_{m_2}\left(\frac{\sqrt{2m_2\rho_1}r_1}{\sqrt{\Omega_2(1-\rho_1)}},\frac{\sqrt{2m_2}r_T}{\sqrt{\Omega_2(1-\rho_1)}}\right)\right]\left[1-Q_{m_1}\left(\frac{\sqrt{2m_1\rho_1}r_2}{\sqrt{\Omega_1(1-\rho_1)}},\frac{\sqrt{2m_1}r_T}{\sqrt{\Omega_1(1-\rho_1)}}\right)\right]+$$

$$+P_2\frac{4(r_1r_2)^{m_2}}{\Gamma(m_2)(1-\rho)\rho_2^{\;(m_2-1)/2}}\left(\frac{m_2}{\Omega_2}\right)^{m_2+1}I_{m_2-1}\left(\frac{2m_2\sqrt{\rho_2}\,r_1r_2}{\Omega_2(1-\rho_2)}\right)e^{-\frac{m_2\left(r_1^{\;2}+r_2^2\right)}{\Omega_2(1-\rho_2)}}+$$

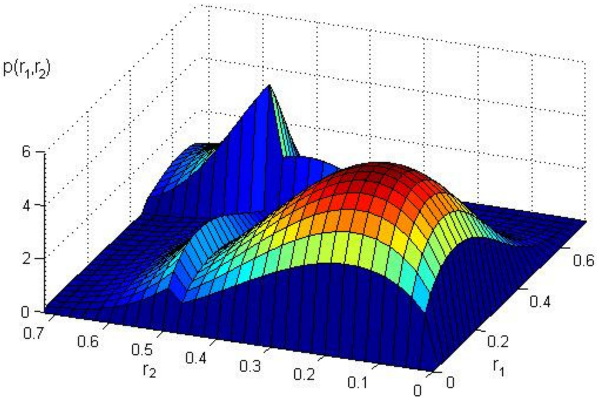
$$+P_2\frac{2m_2^{\;m_2}r_1^{\;2m_2-1}}{\Omega_2^{\;m_2}\Gamma(m_2)}e^{-\frac{m_2r_1^{\;2}}{\Omega_2}}\frac{2m_1^{\;m_1}r_2^{\;2m_1-1}}{\Omega_1^{\;m_1}\Gamma(m_1)}e^{-\frac{m_1r_2^{\;2}}{\Omega_1}}\left[1-Q_{m_2}\left(\frac{\sqrt{2m_2\rho_2}r_1}{\sqrt{\Omega_2(1-\rho_2)}},\frac{\sqrt{2m_2}r_t}{\sqrt{\Omega_2(1-\rho_2)}}\right)\right]+$$

$$+P_2\gamma\left(\frac{m_2}{\Omega_2}r_T^{\;2},m_2\right)\cdot\frac{4(r_1r_2)^{m_1}}{\Gamma(m_1)(1-\rho_1)\rho_1^{\;(m_1-1)/2}}\left(\frac{m_1}{\Omega_1}\right)^{m_1+1}I_{m_1-1}\left(\frac{2m_1\sqrt{\rho_1}\,r_1r_2}{\Omega_1(1-\rho_1)}\right)e^{-\frac{m_1\left(r_1^{\;2}+r_2^2\right)}{\Omega_1(1-\rho_1)}}+$$

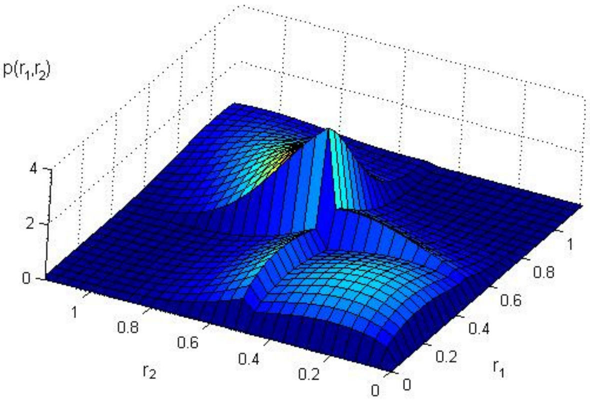
$$+P_2\frac{2m_1^{\;m_1}r_1^{\;2m_1-1}}{\Omega_1^{\;m_1}\Gamma(m_1)}e^{-\frac{m_1r_1^{\;2}}{\Omega_1}}\frac{2m_2^{\;m_2}r_2^{\;2m_2-1}}{\Omega_2^{\;m_2}\Gamma(m_2)}e^{-\frac{m_2r_2^{\;2}}{\Omega_2}}\cdot$$

$$\cdot\left[1-Q_{m_1}\left(\frac{\sqrt{2m_1\rho_1}\,r_1}{\sqrt{\Omega_1(1-\rho_1)}},\frac{\sqrt{2m_1}\,r_t}{\sqrt{\Omega_1(1-\rho_1)}}\right)\right]\left[1-Q_{m_2}\left(\frac{\sqrt{2m_2\rho_2}\,r_2}{\sqrt{\Omega_2(1-\rho_2)}},\frac{\sqrt{2m_2}\,r_t}{\sqrt{\Omega_2(1-\rho_2)}}\right)\right] \qquad (3.4.20)$$

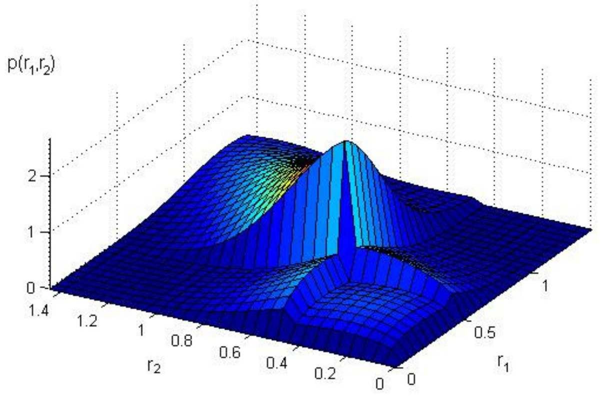
Na slikama 3.3.4.-6. predstavljena je zavisnost PDF od vrednosti signala za različite vrednosti parametara raspodele i praga odlučivanja, gde je pretpostavljeno je da su parametri raspodele isti za obe grane kombinera.



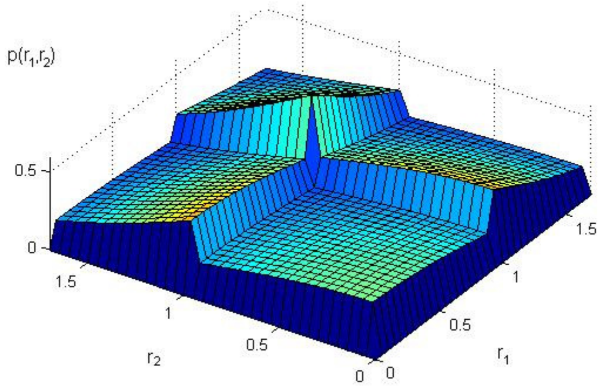
Slika 3.4.1. Združena gustina raspodele verovatnoće na izlazu iz SSC kombinera u dva trenutka vremena u prisustvu Nakagami-m fedinga za parametre: $\rho = 0.8$, $r_T = 0.5$, $m = 0.7$, $\Omega = 0.1$



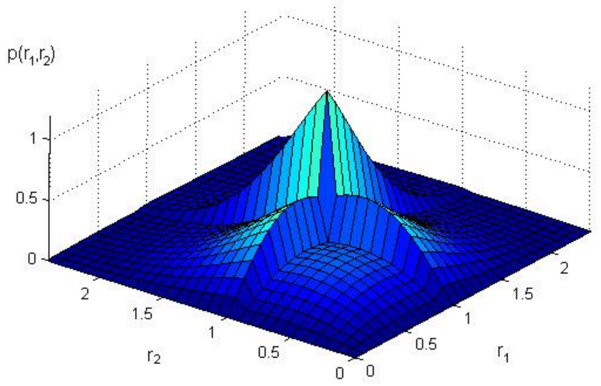
Slika 3.4.2. Združena gustina raspodele verovatnoće na izlazu iz SSC kombinera u dva trenutka vremena u prisustvu Nakagami-m fedinga za parametre: $\rho = 0.8$, $r_T = 0.5$, $m = 0.7$, $\Omega = 0.3$



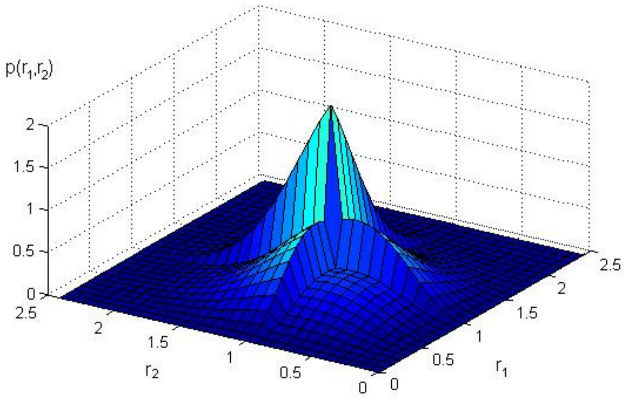
Slika 3.4.3. Združena gustina raspodele verovatnoće na izlazu iz SSC kombinera u dva trenutka vremena u prisustvu Nakagami-m fedinga za parametre: $\rho = 0.8$, $r_T = 0.5$, $m = 0.7$, $\Omega = 0.6$



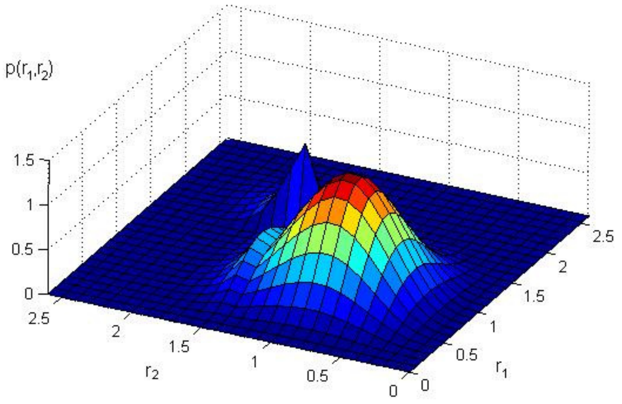
Slika 3.4.4. Združena gustina raspodele verovatnoće na izlazu iz SSC kombinera u dva trenutka vremena u prisustvu Nakagami-m fedinga za parametre: $\rho = 0.1$, $r_T = 1$, $\Omega = 1$, $m = 0.5$



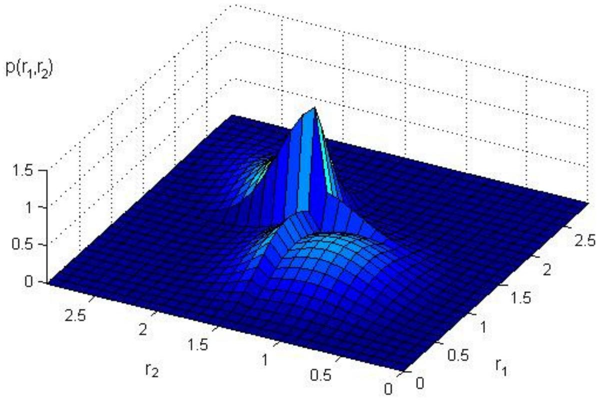
Slika 3.4.5. Združena gustina raspodele verovatnoće na izlazu iz SSC kombinera u dva trenutka vremena u prisustvu Nakagami-m fedinga za parametre: $\rho = 0.1$, $r_T = 1$, $\Omega = 1$, $m = 1$



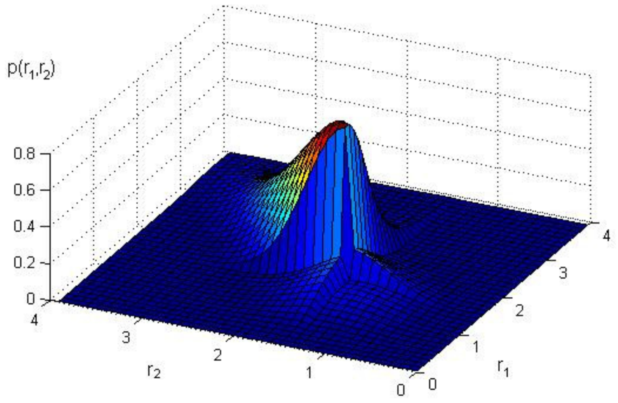
Slika 3.4.6. Združena gustina raspodele verovatnoće na izlazu iz SSC kombinera u dva trenutka vremena u prisustvu Nakagami-m fedinga za parametre: $\rho = 0.1$, $r_T = 1$, $\Omega = 1$, $m = 1.5$



Slika 3.4.7. Združena gustina raspodele verovatnoće na izlazu iz SSC kombinera u dva trenutka vremena u prisustvu Nakagami-m fedinga za parametre: $\rho = 0.8$, $r_T = 1.5$, $m = 2$, $\Omega = 1$



Slika 3.4.8. Združena gustina raspodele verovatnoće na izlazu iz SSC kombinera u dva trenutka vremena u prisustvu Nakagami-m fedinga za parametre: $\rho = 0.8$, $r_T = 1.5$, $m = 2$, $\Omega = 2$



Slika 3.4.9. Združena gustina raspodele verovatnoće na izlazu iz SSC kombinera u dva trenutka vremena u prisustvu Nakagami-m fedinga za parametre: $\rho = 0.8$, $r_T = 1.5$, $m = 2$, $\Omega = 4$

3.5 Združena gustina raspodele verovatnoće na izlazu SSC kombinera u dva trenutka vremena u prisustvu Rice-ovog fedinga

Gustina raspodele verovatnoće i kumulativna raspodela verovatnoće (CDF) signala na izlazu iz kombinera $r_{i,j}$ u prisustvu Rice-ovog fedinga su [6], [7]:

$$p_{r_i}(r_{i,j}) = \frac{r_{i,j}}{\sigma_i^2} e^{-\frac{r_{i,j}^2 + A_i^2}{2\sigma_i^2}} I_0\left(\frac{r_{i,j} A_i}{\sigma_i^2}\right) \quad , \quad r_{i,j} \geq 0 \tag{3.5.1}$$

$$F_{r_i}(r_{i,j}) = 1 - Q_1\left(A_i / \sigma_i, r_{i,j} / \sigma_i\right) \quad , \quad r_{i,j} \geq 0 \tag{3.5.2}$$

gde su $i=1,2$ $j=1,2$, pri čemu je σ_i standardna devijacija, parametar $A_i^2/(2\sigma_i^2)$ predstavlja odnos snaga direktne i reflektovanih komponenti, $I_0(\ )$ je modifikovana Bessel-ova funkcija prve vrste nultog reda, a $Q_1(\ )$ je Marcum-ova Q-funkcija prvog reda.

Verovatnoće P_1 i P_2 se dobijaju ako se u (3.1.17-18) stavi (3.3.35):

$$P_1 = \frac{F_{r_2}(r_T)}{F_{r_1}(r_T) + F_{r_2}(r_T)} = \frac{1 - Q_1\left(A/\sigma_2, r_T/\sigma_2\right)}{2 - \left[Q_1\left(A/\sigma_1, r_T/\sigma_1\right) + Q_1\left(A/\sigma_2, r_T/\sigma_2\right)\right]} \tag{3.5.3}$$

$$P_2 = \frac{F_{r_1}(r_T)}{F_{r_1}(r_T) + F_{r_2}(r_T)} = \frac{1 - Q_1\left(A/\sigma_1, r_T/\sigma_1\right)}{2 - \left[Q_1\left(A/\sigma_1, r_T/\sigma_1\right) + Q_1\left(A/\sigma_2, r_T/\sigma_2\right)\right]} \tag{3.5.4}$$

Združena gustina raspodele verovatnoće korelisanih signala x_1 i x_2 sa Rice-ovom raspodelom i istim parametrima raspodele je [7]:

$$p_{x_1x_2}(x_1,x_2)=\frac{x_1x_2}{\sigma^4(1-\rho^2)}e^{-\frac{x_1{}^2+x_2{}^2+2A^2(1-\rho)}{2\sigma^2(1-\rho^2)}}\cdot$$

$$\cdot\sum_{i=0}^{\infty}\varepsilon_i I_i\left(\frac{\rho x_1x_2}{\sigma^2(1-\rho^2)}\right)I_i\left(\frac{Ax_1}{\sigma^2(1+\rho)}\right)I_i\left(\frac{Ax_2}{\sigma^2(1+\rho)}\right) \tag{3.5.5}$$

gde je ρ koeficijent korelacije, $I_i(\ )$ je modifikovana Bessel-ova funkcija prve vrste i-tog reda (3.3.20), [51], a ε_i je Neumann-ov faktor definisan sa:

$$\varepsilon_i=\begin{cases}1, & i=0\\ 2, & i>0\end{cases} \tag{3.5.6}$$

Združena gustina raspodele verovatnoće signala r_1 i r_2 na izlazu SSC kombinera u dva trenutka vremena u prisustvu Rice-ovog fedinga kada su signali na ulazu u grane kombinera nezavisni, može se dobiti ako se u (3.2.5-8) stave izrazi (3.3.34) i (3.3.38)

Za $r_1<r_T$, $r_2<r_T$

$$p_{r_1r_2}(r_1,r_2)=P_1\int_0^{r_T}\frac{r_{11}r_2}{\sigma_1{}^4(1-\rho_1{}^2)}e^{-\frac{r_{11}{}^2+r_2{}^2+2A_1{}^2(1-\rho_1)}{2\sigma_1{}^2(1-\rho_1{}^2)}}\sum_{i=0}^{\infty}\varepsilon_i I_i\left(\frac{\rho_1 r_{11}r_2}{\sigma_1{}^2(1-\rho_1{}^2)}\right)I_i\left(\frac{A_1r_{11}}{\sigma_1{}^2(1+\rho_1)}\right)I_i\left(\frac{A_1r_2}{\sigma_1{}^2(1+\rho_1)}\right)dr_{11}\cdot$$

$$\cdot\int_0^{r_T}\frac{r_{22}r_1}{\sigma_2{}^4(1-\rho_2{}^2)}e^{-\frac{r_{22}{}^2+r_1{}^2+2A_2{}^2(1-\rho_2)}{2\sigma_2{}^2(1-\rho_2{}^2)}}\sum_{i=0}^{\infty}\varepsilon_i I_i\left(\frac{\rho_2 r_{22}r_1}{\sigma_2{}^2(1-\rho_2{}^2)}\right)I_i\left(\frac{A_2r_{22}}{\sigma_2{}^2(1+\rho_2)}\right)I_i\left(\frac{A_2r_1}{\sigma_2{}^2(1+\rho_2)}\right)dr_{22}+$$

$$+P_2\int_0^{r_T}\frac{r_{21}r_2}{\sigma_2{}^4(1-\rho_2{}^2)}e^{-\frac{r_{21}{}^2+r_2{}^2+2A_2{}^2(1-\rho_2)}{2\sigma_2{}^2(1-\rho_2{}^2)}}\sum_{i=0}^{\infty}\varepsilon_i I_i\left(\frac{\rho_2 r_{21}r_2}{\sigma_2{}^2(1-\rho_2{}^2)}\right)I_i\left(\frac{A_2r_{21}}{\sigma_2{}^2(1+\rho_2)}\right)I_i\left(\frac{A_2r_2}{\sigma_2{}^2(1+\rho_2)}\right)dr_{21}\cdot$$

$$\cdot\int_0^{r_T}\frac{r_{12}r_1}{\sigma_1{}^4(1-\rho_1{}^2)}e^{-\frac{r_{12}{}^2+r_1{}^2+2A_1{}^2(1-\rho_1)}{2\sigma_1{}^2(1-\rho\rho_1{}^2)}}\sum_{i=0}^{\infty}\varepsilon_i I_i\left(\frac{\rho_1 r_{12}r_1}{\sigma_1{}^2(1-\rho_1{}^2)}\right)I_i\left(\frac{A_1r_{12}}{\sigma_1{}^2(1+\rho_1)}\right)I_i\left(\frac{A_1r_1}{\sigma_1{}^2(1+\rho_1)}\right)dr_{12} \tag{3.5.7}$$

Za $r_1\geq r_T$, $r_2<r_T$

$$p_{r_1r_2}(r_1,r_2)=P_1\frac{r_2}{\sigma_2{}^2}e^{-\frac{r_2{}^2+A_2{}^2}{2\sigma_2{}^2}}I_0\left(\frac{r_2A_2}{\sigma_2{}^2}\right)\cdot$$

$$\cdot\int_0^{r_T}\frac{r_{12}r_1}{\sigma_1{}^4(1-\rho_1{}^2)}e^{-\frac{r_{12}{}^2+r_1{}^2+2A_1{}^2(1-\rho_1)}{2\sigma_1{}^2(1-\rho_1{}^2)}}\sum_{i=0}^{\infty}\varepsilon_i I_i\left(\frac{\rho_1 r_{12}r_1}{\sigma_1{}^2(1-\rho_1{}^2)}\right)I_i\left(\frac{A_1r_{12}}{\sigma_1{}^2(1+\rho_1)}\right)I_i\left(\frac{A_1r_1}{\sigma_1{}^2(1+\rho_1)}\right)dr_{12}+$$

$$+P_1\int_0^{r_T}\frac{r_{11}r_2}{\sigma_1{}^4(1-\rho_1{}^2)}e^{-\frac{r_{11}{}^2+r_2{}^2+2A_1{}^2(1-\rho_1)}{2\sigma_1{}^2(1-\rho_1{}^2)}}\sum_{i=0}^{\infty}\varepsilon_i I_i\left(\frac{\rho_1 r_{11}r_2}{\sigma_1{}^2(1-\rho_1{}^2)}\right)I_i\left(\frac{A_1r_{11}}{\sigma_1{}^2(1+\rho_1)}\right)I_i\left(\frac{A_1r_2}{\sigma_1{}^2(1+\rho_1)}\right)dr_{11}\cdot$$

$$\cdot\int_0^{r_T}\frac{r_{22}r_1}{\sigma_2^4(1-\rho_2^2)}e^{-\frac{r_{22}^2+r_1^2+2A_2^2(1-\rho_2)}{2\sigma_2^2(1-\rho_2^2)}}\sum_{i=0}^{\infty}\varepsilon_i I_i\left(\frac{\rho_2 r_{22}r_1}{\sigma_2^2(1-\rho_2^2)}\right)I_i\left(\frac{A_2r_{22}}{\sigma_2^2(1+\rho_2)}\right)I_i\left(\frac{A_2r_1}{\sigma_2^2(1+\rho_2)}\right)dr_{22}+$$

$$+P_2\frac{r_2}{\sigma_1^2}e^{-\frac{r_2^2+A_1^2}{2\sigma_1^2}}I_0\left(\frac{r_2A_1}{\sigma_1^2}\right)\cdot$$

$$\cdot\int_0^{r_T}\frac{r_{22}r_1}{\sigma_2^4(1-\rho_2^2)}e^{-\frac{r_{22}^2+r_1^2+2A_2^2(1-\rho_2)}{2\sigma_2^2(1-\rho_2^2)}}\sum_{i=0}^{\infty}\varepsilon_i I_i\left(\frac{\rho_2 r_{22}r_1}{\sigma_2^2(1-\rho_2^2)}\right)I_i\left(\frac{A_2r_{22}}{\sigma_2^2(1+\rho_2)}\right)I_i\left(\frac{A_2r_1}{\sigma_2^2(1+\rho_2)}\right)dr_{22}+$$

$$+P_2\int_0^{r_T}\frac{r_{21}r_2}{\sigma_2^4(1-\rho_2^2)}e^{-\frac{r_{21}^2+r_2^2+2A_2^2(1-\rho_2)}{2\sigma_2^2(1-\rho_2^2)}}\sum_{i=0}^{\infty}\varepsilon_i I_i\left(\frac{\rho_2 r_{21}r_2}{\sigma_2^2(1-\rho_2^2)}\right)I_i\left(\frac{A_2r_{21}}{\sigma_2^2(1+\rho_2)}\right)I_i\left(\frac{A_2r_2}{\sigma_2^2(1+\rho_2)}\right)dr_{21}\cdot$$

$$\cdot\int_0^{r_T}\frac{r_{12}r_1}{\sigma_1^4(1-\rho_1^2)}e^{-\frac{r_{12}^2+r_1^2+2A_1^2(1-\rho_1)}{2\sigma_1^2(1-\rho\rho_1^2)}}\sum_{i=0}^{\infty}\varepsilon_i I_i\left(\frac{\rho_1 r_{12}r_1}{\sigma_1^2(1-\rho_1^2)}\right)I_i\left(\frac{A_1r_{12}}{\sigma_1^2(1+\rho_1)}\right)I_i\left(\frac{A_1r_1}{\sigma_1^2(1+\rho_1)}\right)dr_{12}\quad(3.5.8)$$

Za $r_1<r_T$, $r_2\geq r_T$

$$p_{r_1r_2}(r_1,r_2)=P_1\left(1-Q_1\left(A/\sigma_1,r_t/\sigma_1\right)\right)\cdot$$

$$\cdot\frac{r_1r_2}{\sigma_2^4(1-\rho_2^2)}e^{-\frac{r_1^2+r_2^2+2A_2^2(1-\rho_2)}{2\sigma_2^2(1-\rho_2^2)}}\sum_{i=0}^{\infty}\varepsilon_i I_i\left(\frac{\rho_2 r_1r_2}{\sigma_2^2(1-\rho_2^2)}\right)I_i\left(\frac{A_2r_1}{\sigma_2^2(1+\rho_2)}\right)I_i\left(\frac{A_2r_2}{\sigma_2^2(1+\rho_2)}\right)+$$

$$+P_1\int_0^{r_T}\frac{r_{11}r_2}{\sigma_1^4(1-\rho_1^2)}e^{-\frac{r_{11}^2+r_2^2+2A_1^2(1-\rho_1)}{2\sigma_1^2(1-\rho_1^2)}}\sum_{i=0}^{\infty}\varepsilon_i I_i\left(\frac{\rho_1 r_{11}r_2}{\sigma_1^2(1-\rho_1^2)}\right)I_i\left(\frac{A_1r_{11}}{\sigma_1^2(1+\rho_1)}\right)I_i\left(\frac{A_1r_2}{\sigma_1^2(1+\rho_1)}\right)dr_{11}\cdot$$

$$\cdot\int_0^{r_T}\frac{r_{22}r_1}{\sigma_2^4(1-\rho_2^2)}e^{-\frac{r_{22}^2+r_1^2+2A_2^2(1-\rho_2)}{2\sigma_2^2(1-\rho_2^2)}}\sum_{i=0}^{\infty}\varepsilon_i I_i\left(\frac{\rho_2 r_{22}r_1}{\sigma_2^2(1-\rho_2^2)}\right)I_i\left(\frac{A_2r_{22}}{\sigma_2^2(1+\rho_2)}\right)I_i\left(\frac{A_2r_1}{\sigma_2^2(1+\rho_2)}\right)dr_{22}+$$

$$+P_2\left(1-Q_1\left(A/\sigma_2,r_t/\sigma_2\right)\right)\cdot$$

$$\cdot\frac{r_1r_2}{\sigma_1^4(1-\rho_1^2)}e^{-\frac{r_1^2+r_2^2+2A_1^2(1-\rho_1)}{2\sigma_1^2(1-\rho_1^2)}}\sum_{i=0}^{\infty}\varepsilon_i I_i\left(\frac{\rho_1 r_1r_2}{\sigma_1^2(1-\rho_1^2)}\right)I_i\left(\frac{A_1r_1}{\sigma_1^2(1+\rho_1)}\right)I_i\left(\frac{A_1r_2}{\sigma_1^2(1+\rho_1)}\right)+$$

$$+P_2\int_0^{r_T}\frac{r_{21}r_2}{\sigma_2^4(1-\rho_2^2)}e^{-\frac{r_{21}^2+r_2^2+2A_2^2(1-\rho_2)}{2\sigma_2^2(1-\rho_2^2)}}\sum_{i=0}^{\infty}\varepsilon_i I_i\left(\frac{\rho_2 r_{21}r_2}{\sigma_2^2(1-\rho_2^2)}\right)I_i\left(\frac{A_2r_{21}}{\sigma_2^2(1+\rho_2)}\right)I_i\left(\frac{A_2r_2}{\sigma_2^2(1+\rho_2)}\right)dr_{21}\cdot$$

$$\cdot\int_0^{r_T}\frac{r_{12}r_1}{\sigma_1^4(1-\rho_1^2)}e^{-\frac{r_{12}^2+r_1^2+2A_1^2(1-\rho_1)}{2\sigma_1^2(1-\rho\rho_1^2)}}\sum_{i=0}^{\infty}\varepsilon_i I_i\left(\frac{\rho_1 r_{12}r_1}{\sigma_1^2(1-\rho_1^2)}\right)I_i\left(\frac{A_1r_{12}}{\sigma_1^2(1+\rho_1)}\right)I_i\left(\frac{A_1r_1}{\sigma_1^2(1+\rho_1)}\right)dr_{12}\quad(3.5.9)$$

Za $r_1\geq r_T$, $r_2\geq r_T$

$$p_{r_1 r_2}(r_1, r_2) = P_1 \frac{r_1 r_2}{\sigma_1^{4}(1-\rho_1^{2})} e^{-\frac{r_1^2 + r_2^2 + 2A_1^2(1-\rho_1)}{2\sigma_1^2(1-\rho_1^2)}} \sum_{i=0}^{\infty} \varepsilon_i I_i\left(\frac{\rho_1 r_1 r_2}{\sigma_1^2(1-\rho_1^2)}\right) I_i\left(\frac{A_1 r_1}{\sigma_1^2(1+\rho_1)}\right) I_i\left(\frac{A_1 r_2}{\sigma_1^2(1+\rho_1)}\right) +$$

$$+ P_1 \frac{r_2}{\sigma_2^2} e^{-\frac{r_2^2 + A_2^2}{2\sigma_2^2}} I_0\left(\frac{r_2 A_2}{\sigma_2^2}\right) \cdot$$

$$\cdot \int_0^{r_T} \frac{r_{12} r_1}{\sigma_1^{4}(1-\rho_1^{2})} e^{-\frac{r_{12}^2 + r_1^2 + 2A_1^2(1-\rho_1)}{2\sigma_1^2(1-\rho_1^2)}} \sum_{i=0}^{\infty} \varepsilon_i I_i\left(\frac{\rho_1 r_{12} r_1}{\sigma_1^2(1-\rho_1^2)}\right) I_i\left(\frac{A_1 r_{12}}{\sigma_1^2(1+\rho_1)}\right) I_i\left(\frac{A_1 r_1}{\sigma_1^2(1+\rho_1)}\right) dr_{12} +$$

$$+ P_1\left(1 - Q_1\left(A/\sigma_1, r_t/\sigma_1\right)\right) \cdot$$

$$\cdot \frac{r_1 r_2}{\sigma_2^{4}(1-\rho_2^{2})} e^{-\frac{r_1^2 + r_2^2 + 2A_2^2(1-\rho_2)}{2\sigma_2^2(1-\rho_2^2)}} \sum_{i=0}^{\infty} \varepsilon_i I_i\left(\frac{\rho_2 r_1 r_2}{\sigma_2^2(1-\rho_2^2)}\right) I_i\left(\frac{A_2 r_1}{\sigma_2^2(1+\rho_2)}\right) I_i\left(\frac{A_2 r_2}{\sigma_2^2(1+\rho_2)}\right) +$$

$$+ P_1 \int_0^{r_T} \frac{r_{11} r_2}{\sigma_1^{4}(1-\rho_1^{2})} e^{-\frac{r_{11}^2 + r_2^2 + 2A_1^2(1-\rho_1)}{2\sigma_1^2(1-\rho_1^2)}} \sum_{i=0}^{\infty} \varepsilon_i I_i\left(\frac{\rho_1 r_{11} r_2}{\sigma_1^2(1-\rho_1^2)}\right) I_i\left(\frac{A_1 r_{11}}{\sigma_1^2(1+\rho_1)}\right) I_i\left(\frac{A_1 r_2}{\sigma_1^2(1+\rho_1)}\right) dr_{11} \cdot$$

$$\cdot \int_0^{r_T} \frac{r_{22} r_1}{\sigma_2^{4}(1-\rho_2^{2})} e^{-\frac{r_{22}^2 + r_1^2 + 2A_2^2(1-\rho_2)}{2\sigma_2^2(1-\rho_2^2)}} \sum_{i=0}^{\infty} \varepsilon_i I_i\left(\frac{\rho_2 r_{22} r_1}{\sigma_2^2(1-\rho_2^2)}\right) I_i\left(\frac{A_2 r_{22}}{\sigma_2^2(1+\rho_2)}\right) I_i\left(\frac{A_2 r_1}{\sigma_2^2(1+\rho_2)}\right) dr_{22} +$$

$$+ P_2 \frac{r_1 r_2}{\sigma_2^{4}(1-\rho_2^{2})} e^{-\frac{r_1^2 + r_2^2 + 2A_2^2(1-\rho_2)}{2\sigma_2^2(1-\rho_2^2)}} \sum_{i=0}^{\infty} \varepsilon_i I_i\left(\frac{\rho_2 r_1 r_2}{\sigma_2^2(1-\rho_2^2)}\right) I_i\left(\frac{A_2 r_1}{\sigma_2^2(1+\rho_2)}\right) I_i\left(\frac{A_2 r_2}{\sigma_2^2(1+\rho_2)}\right) +$$

$$+ P_2 \frac{r_2}{\sigma_1^2} e^{-\frac{r_2^2 + A_1^2}{2\sigma_1^2}} I_0\left(\frac{r_2 A_1}{\sigma_1^2}\right) \cdot$$

$$\cdot \int_0^{r_T} \frac{r_{22} r_1}{\sigma_2^{4}(1-\rho_2^{2})} e^{-\frac{r_{22}^2 + r_1^2 + 2A_2^2(1-\rho_2)}{2\sigma_2^2(1-\rho_2^2)}} \sum_{i=0}^{\infty} \varepsilon_i I_i\left(\frac{\rho_2 r_{22} r_1}{\sigma_2^2(1-\rho_2^2)}\right) I_i\left(\frac{A_2 r_{22}}{\sigma_2^2(1+\rho_2)}\right) I_i\left(\frac{A_2 r_1}{\sigma_2^2(1+\rho_2)}\right) dr_{22} +$$

$$+ P_2\left(1 - Q_1\left(A/\sigma_2, r_t/\sigma_2\right)\right) \cdot$$

$$\cdot \frac{r_1 r_2}{\sigma_1^{4}(1-\rho_1^{2})} e^{-\frac{r_1^2 + r_2^2 + 2A_1^2(1-\rho_1)}{2\sigma_1^2(1-\rho_1^2)}} \sum_{i=0}^{\infty} \varepsilon_i I_i\left(\frac{\rho_1 r_1 r_2}{\sigma_1^2(1-\rho_1^2)}\right) I_i\left(\frac{A_1 r_1}{\sigma_1^2(1+\rho_1)}\right) I_i\left(\frac{A_1 r_2}{\sigma_1^2(1+\rho_1)}\right) +$$

$$+ P_2 \int_0^{r_T} \frac{r_{21} r_2}{\sigma_2^{4}(1-\rho_2^{2})} e^{-\frac{r_{21}^2 + r_2^2 + 2A_2^2(1-\rho_2)}{2\sigma_2^2(1-\rho_2^2)}} \sum_{i=0}^{\infty} \varepsilon_i I_i\left(\frac{\rho_2 r_{21} r_2}{\sigma_2^2(1-\rho_2^2)}\right) I_i\left(\frac{A_2 r_{21}}{\sigma_2^2(1+\rho_2)}\right) I_i\left(\frac{A_2 r_2}{\sigma_2^2(1+\rho_2)}\right) dr_{21} \cdot$$

$$\cdot \int_0^{r_T} \frac{r_{12} r_1}{\sigma_1^{4}(1-\rho_1^{2})} e^{-\frac{r_{12}^2 + r_1^2 + 2A_1^2(1-\rho_1)}{2\sigma_1^2(1-\rho\rho_1^2)}} \sum_{i=0}^{\infty} \varepsilon_i I_i\left(\frac{\rho_1 r_{12} r_1}{\sigma_1^2(1-\rho_1^2)}\right) I_i\left(\frac{A_1 r_{12}}{\sigma_1^2(1+\rho_1)}\right) I_i\left(\frac{A_1 r_1}{\sigma_1^2(1+\rho_1)}\right) dr_{12} \tag{3.5.10}$$

Za celobrojne pozitivne vrednosti *m* i *k*, modifikovana Bessel-ova funkcija prve vrste *m*-tog reda se može predstaviti u obliku sledećeg reda [7]:

$$I_m(x)=\sum_{k=0}^{\infty}\frac{1}{k!(m+k)!}\left(\frac{x}{2}\right)^{m+2k} \tag{3.5.11}$$

Izrazi (3.3.40-43) su u obliku jednostrukog integrala sa konačnim granicama. Združena gustina raspodele verovatnoće se može dobiti u zatvorenom obliku korišćenjem nekompletne gamma funkcije [1]:

$$\gamma(\alpha,z)=\int_0^z x^{\alpha-1}\exp(-x)dx \qquad \mathrm{Re}(\alpha)>0 \tag{3.5.12}$$

Za predstavljanje združene PDF u zatvorenom obliku potrebno je rešiti integral $\int_{r_T}^{\infty} p_{x_1x_2}(x_1,x_2)dx_1$, gde je $p_{x_1x_2}(x_1,x_2)$ dato u (3.3.38). Transformacijom $p_{x_1x_2}(x_1,x_2)$, ona se može predstaviti u obliku koji u podintegralnom delu predstavlja podintegralni deo nekompletne gamma funkcije, tako što se se sve modifikovane Bessel-ove funkcije prve vrste razviju u red i izraz preuredi u odgovarajući oblik.

$$p_{x_1x_2}(x_1,x_2)=\frac{1}{\sigma^4(1-\rho^2)}e^{-\frac{A^2}{\sigma^2(1+\rho)}}\sum_{i,l_1,l_2,l_3=0}^{\infty}\varepsilon_i\cdot\frac{1}{l_1!l_2!l_3!(i+l_1)!(i+l_2)!(i+l_3)!}\cdot$$

$$\cdot\frac{\rho^{i+2l_1}}{\left(2\sigma^2(1-\rho^2)\right)^{3i+2l_1+2l_2+2l_3}}A^{2i+2l_2+2l_3}(1-\rho)^{2i+2l_2+2l_3}x_1^{2i+2l_1+2l_2+1}x_2^{2i+2l_1+2l_3+1}e^{-\frac{x_1^2+x_2^2}{2\sigma^2(1-\rho^2)}}$$

(3.5.13)

Integral se rešava uvođenjem smene:

$$x_1=\sigma\sqrt{2(1-\rho^2)}\sqrt{x} \qquad x=\frac{x_1^2}{2\sigma^2(1-\rho^2)} \tag{3.5.14}$$

$$\int_0^{r_T}p_{x_1x_2}(x_1,x_2)dx_1=\frac{1}{\sigma^4(1-\rho^2)}e^{-\frac{A^2}{\sigma^2(1+\rho)}}\cdot$$

$$\cdot\sum_{i,l_1,l_2,l_3=0}^{\infty}\varepsilon_i\cdot\frac{1}{l_1!l_2!l_3!(i+l_1)!(i+l_2)!(i+l_3)!}\frac{\rho^{i+2l_1}}{\left(2\sigma^2(1-\rho^2)\right)^{3i+2l_1+2l_2+2l_3}}A^{2i+2l_2+2l_3}(1-\rho)^{2i+2l_2+2l_3}\cdot$$

$$\cdot x_2^{2i+2l_1+2l_3+1}e^{-\frac{x_2^2}{2\sigma^2(1-\rho^2)}}\int_0^{\frac{r_t^2}{2\sigma^2(1-\rho^2)}}\left(\sigma\sqrt{2(1-\rho^2)}\sqrt{x}\right)^{2i+2l_1+2l_2+1}e^{-x}\sigma\sqrt{2(1-\rho^2)}\frac{1}{2}x^{-1/2}dx \tag{3.5.15}$$

Nakon određenih algebarskih preuređivanja dobija se oblik koji odgovara nekompletnoj gamma funkciji.

$$\int_0^{r_t} p_{x_1x_2}(x_1,x_2)dx_1 = \frac{1}{\sigma^2} e^{-\frac{A^2}{\sigma^2(1+\rho)}} \sum_{i,l_1,l_2,l_3=0}^{\infty} \varepsilon_i \cdot \frac{1}{l_1!l_2!l_3!(i+l_1)!(i+l_2)!(i+l_3)!} \cdot$$

$$\cdot \frac{\rho^{i+2l_1}}{\left(2\sigma^2(1-\rho^2)\right)^{2i+l_1+l_2+2l_3}} A^{2i+2l_2+2l_3}(1-\rho)^{2i+2l_2+2l_3} \cdot$$

$$\cdot\, x_2^{2i+2l_1+2l_3+1} e^{-\frac{x_2^2}{2\sigma^2(1-\rho^2)}} \int_0^{\frac{r_t^2}{2\sigma^2(1-\rho^2)}} (x)^{i+l_1+l_2+1-1} e^{-x} dx \qquad (3.5.16)$$

Krajnje rešenje je u zatvorenom obliku uz korišćenje 4 beskonačne sume.

$$\int_0^{r_T} p_{x_1x_2}(x_1,x_2)dx_1 = \frac{1}{\sigma^2} e^{-\frac{A^2}{\sigma^2(1+\rho)}} \sum_{i,l_1,l_2,l_3=0}^{\infty} \varepsilon_i \cdot \frac{1}{l_1!l_2!l_3!(i+l_1)!(i+l_2)!(i+l_3)!} \frac{\rho^{i+2l_1}}{\left(2\sigma^2(1-\rho^2)\right)^{2i+l_1+l_2+2l_3}} \cdot$$

$$\cdot\, A^{2i+2l_2+2l_3}(1-\rho)^{2i+2l_2+2l_3} x_2^{2i+2l_1+2l_3+1} e^{-\frac{x_2^2}{2\sigma^2(1-\rho^2)}} \gamma\left(i+l_1+l_2+1, \frac{r_t^2}{2\sigma^2(1-\rho^2)}\right) \qquad (3.5.17)$$

Zamenom (3.5.17) u izrazima (3.5.7-10) dobija se konačni oblik za združenu gustinu raspodele verovatnoće na izlazu iz SSC kombinera

Za $r_1<r_T$, $r_2<r_T$

$$p_{r_1r_2}(r_1,r_2) = P_1\left[\frac{1}{\sigma_2^2} e^{-\frac{A_2^2}{\sigma_2^2(1+\rho_2)}} \sum_{i,l_1,l_2,l_3=0}^{\infty} \varepsilon_i \cdot \frac{1}{l_1!l_2!l_3!(i+l_1)!(i+l_2)!(i+l_3)!} \frac{\rho_2^{i+2l_1}}{\left(2\sigma_2^2(1-\rho_2^2)\right)^{2i+l_1+l_2+2l_3}} \cdot\right.$$

$$\left.\cdot\, A_2^{2i+2l_2+2l_3}(1-\rho_2)^{2i+2l_2+2l_3} \cdot r_1^{2i+2l_1+2l_3+1} e^{-\frac{r_1^2}{2\sigma_2^2(1-\rho_2^2)}} \gamma\left(i+l_1+l_2+1, \frac{r_T^2}{2\sigma_2^2(1-\rho_2^2)}\right)\right] \cdot$$

$$\cdot\left[\frac{1}{\sigma_1^2} e^{-\frac{A_1^2}{\sigma_1^2(1+\rho_1)}} \sum_{i,l_1,l_2,l_3=0}^{\infty} \varepsilon_i \cdot \frac{1}{l_1!l_2!l_3!(i+l_1)!(i+l_2)!(i+l_3)!} \frac{\rho_1^{i+2l_1}}{\left(2\sigma_1^2(1-\rho_1^2)\right)^{2i+l_1+l_2+2l_3}} \cdot\right.$$

$$\left.\cdot\, A_1^{2i+2l_2+2l_3}(1-\rho_1)^{2i+2l_2+2l_3} \cdot r_2^{2i+2l_1+2l_3+1} e^{-\frac{r_2^2}{2\sigma_1^2(1-\rho_1^2)}} \gamma\left(i+l_1+l_2+1, \frac{r_T^2}{2\sigma_1^2(1-\rho_1^2)}\right)\right] +$$

$$+ P_2\left[\frac{1}{\sigma_1^2} e^{-\frac{A_1^2}{\sigma_1^2(1+\rho_1)}} \sum_{i,l_1,l_2,l_3=0}^{\infty} \varepsilon_i \cdot \frac{1}{l_1!l_2!l_3!(i+l_1)!(i+l_2)!(i+l_3)!} \frac{\rho_1^{i+2l_1}}{\left(2\sigma_1^2(1-\rho_1^2)\right)^{2i+l_1+l_2+2l_3}} \cdot\right.$$

$$\cdot A_1^{2i+2l_2+2l_3}(1-\rho_1)^{2i+2l_2+2l_3}\cdot r_1^{2i+2l_1+2l_3+1}e^{-\frac{r_1^2}{2\sigma_1^2(1-\rho_1^2)}}\gamma\left(i+l_1+l_2+1,\frac{r_T^2}{2\sigma_1^2(1-\rho_1^2)}\right)\Bigg]\cdot$$

$$\cdot\left[\frac{1}{\sigma_2^2}e^{-\frac{A_2^2}{\sigma_2^2(1+\rho_2)}}\sum_{i,l_1,l_2,l_3=0}^{\infty}\varepsilon_i\cdot\frac{1}{l_1!l_2!l_3!(i+l_1)!(i+l_2)!(i+l_3)!}\frac{\rho_2^{i+2l_1}}{\left(2\sigma_2^2(1-\rho_2^2)\right)^{2i+l_1+l_2+2l_3}}\cdot\right.$$

$$\left.\cdot A_2^{2i+2l_2+2l_3}(1-\rho_2)^{2i+2l_2+2l_3}\cdot r_2^{2i+2l_1+2l_3+1}e^{-\frac{r_2^2}{2\sigma_2^2(1-\rho_2^2)}}\gamma\left(i+l_1+l_2+1,\frac{r_T^2}{2\sigma_2^2(1-\rho_2^2)}\right)\right] \quad (3.5.18)$$

Za $r_1 \geq r_T$, $r_2 < r_T$

$$p_{r_1r_2}(r_1,r_2)=P_1\frac{r_2}{\sigma_2^2}e^{-\frac{r_2^2+A_2^2}{2\sigma_2^2}}I_0\left(\frac{r_2A_2}{\sigma_2^2}\right)\cdot$$

$$\cdot\left[\frac{1}{\sigma_1^2}e^{-\frac{A_1^2}{\sigma_1^2(1+\rho_1)}}\sum_{i,l_1,l_2,l_3=0}^{\infty}\varepsilon_i\cdot\frac{1}{l_1!l_2!l_3!(i+l_1)!(i+l_2)!(i+l_3)!}\frac{\rho_1^{i+2l_1}}{\left(2\sigma_1^2(1-\rho_1^2)\right)^{2i+l_1+l_2+2l_3}}\cdot\right.$$

$$\left.\cdot A_1^{2i+2l_2+2l_3}(1-\rho_1)^{2i+2l_2+2l_3}\cdot r_1^{2i+2l_1+2l_3+1}e^{-\frac{r_1^2}{2\sigma_1^2(1-\rho_1^2)}}\gamma\left(i+l_1+l_2+1,\frac{r_T^2}{2\sigma_1^2(1-\rho_1^2)}\right)\right]+$$

$$+P_1\left[\frac{1}{\sigma_2^2}e^{-\frac{A_2^2}{\sigma_2^2(1+\rho_2)}}\sum_{i,l_1,l_2,l_3=0}^{\infty}\varepsilon_i\cdot\frac{1}{l_1!l_2!l_3!(i+l_1)!(i+l_2)!(i+l_3)!}\frac{\rho_2^{i+2l_1}}{\left(2\sigma_2^2(1-\rho_2^2)\right)^{2i+l_1+l_2+2l_3}}\cdot\right.$$

$$\left.\cdot A_2^{2i+2l_2+2l_3}(1-\rho_2)^{2i+2l_2+2l_3}\cdot r_1^{2i+2l_1+2l_3+1}e^{-\frac{r_1^2}{2\sigma_2^2(1-\rho_2^2)}}\gamma\left(i+l_1+l_2+1,\frac{r_T^2}{2\sigma_2^2(1-\rho_2^2)}\right)\right]\cdot$$

$$\cdot\left[\frac{1}{\sigma_1^2}e^{-\frac{A_1^2}{\sigma_1^2(1+\rho_1)}}\sum_{i,l_1,l_2,l_3=0}^{\infty}\varepsilon_i\cdot\frac{1}{l_1!l_2!l_3!(i+l_1)!(i+l_2)!(i+l_3)!}\frac{\rho_1^{i+2l_1}}{\left(2\sigma_1^2(1-\rho_1^2)\right)^{2i+l_1+l_2+2l_3}}\cdot\right.$$

$$\left.\cdot A_1^{2i+2l_2+2l_3}(1-\rho_1)^{2i+2l_2+2l_3}\cdot r_2^{2i+2l_1+2l_3+1}e^{-\frac{r_2^2}{2\sigma_1^2(1-\rho_1^2)}}\gamma\left(i+l_1+l_2+1,\frac{r_T^2}{2\sigma_1^2(1-\rho_1^2)}\right)\right]+$$

$$+P_2\frac{r_2}{\sigma_1^2}e^{-\frac{r_2^2+A_1^2}{2\sigma_1^2}}I_0\left(\frac{r_2A_1}{\sigma_1^2}\right)\cdot$$

$$\cdot\left[\frac{1}{\sigma_2^2}e^{-\frac{A_2^2}{\sigma_2^2(1+\rho_2)}}\sum_{i,l_1,l_2,l_3=0}^{\infty}\varepsilon_i\cdot\frac{1}{l_1!l_2!l_3!(i+l_1)!(i+l_2)!(i+l_3)!}\frac{\rho_2^{i+2l_1}}{\left(2\sigma_2^2(1-\rho_2^2)\right)^{2i+l_1+l_2+2l_3}}\cdot\right.$$

$$\left.\cdot A_2^{2i+2l_2+2l_3}(1-\rho_2)^{2i+2l_2+2l_3}\cdot r_1^{2i+2l_1+2l_3+1}e^{-\frac{r_1^2}{2\sigma_2^2(1-\rho_2^2)}}\gamma\left(i+l_1+l_2+1,\frac{r_T^2}{2\sigma_2^2(1-\rho_2^2)}\right)\right]\cdot$$

$$+P_2\left[\frac{1}{\sigma_1^2}e^{-\frac{A_1^2}{\sigma_1^2(1+\rho_1)}}\sum_{i,l_1,l_2,l_3=0}^{\infty}\varepsilon_i\cdot\frac{1}{l_1!l_2!l_3!(i+l_1)!(i+l_2)!(i+l_3)!}\frac{\rho_1^{i+2l_1}}{\left(2\sigma_1^2(1-\rho_1^2)\right)^{2i+l_1+l_2+2l_3}}\cdot\right.$$

$$\left.\cdot A_1^{2i+2l_2+2l_3}(1-\rho_1)^{2i+2l_2+2l_3}\cdot r_1^{2i+2l_1+2l_3+1}e^{-\frac{r_1^2}{2\sigma_1^2(1-\rho_1^2)}}\gamma\left(i+l_1+l_2+1,\frac{r_T^2}{2\sigma_1^2(1-\rho_1^2)}\right)\right]\cdot$$

$$\left.\cdot A_2^{2i+2l_2+2l_3}(1-\rho_2)^{2i+2l_2+2l_3}\cdot r_2^{2i+2l_1+2l_3+1}e^{-\frac{r_2^2}{2\sigma_2^2(1-\rho_2^2)}}\gamma\left(i+l_1+l_2+1,\frac{r_T^2}{2\sigma_2^2(1-\rho_2^2)}\right)\right]$$

$$\cdot\left[\frac{1}{\sigma_2^2}e^{-\frac{A_2^2}{\sigma_2^2(1+\rho_2)}}\sum_{i,l_1,l_2,l_3=0}^{\infty}\varepsilon_i\cdot\frac{1}{l_1!l_2!l_3!(i+l_1)!(i+l_2)!(i+l_3)!}\frac{\rho_2^{i+2l_1}}{\left(2\sigma_2^2(1-\rho_2^2)\right)^{2i+l_1+l_2+2l_3}}\cdot\right.$$

$$\left.\cdot A_2^{2i+2l_2+2l_3}(1-\rho_2)^{2i+2l_2+2l_3}\cdot r_2^{2i+2l_1+2l_3+1}e^{-\frac{r_2^2}{2\sigma_2^2(1-\rho_2^2)}}\gamma\left(i+l_1+l_2+1,\frac{r_T^2}{2\sigma_2^2(1-\rho_2^2)}\right)\right]\quad(3.5.19)$$

Za $r_1<r_T$, $r_2\geq r_T$

$$p_{r_1r_2}(r_1,r_2)=P_1\left(1-Q_1\left(A/\sigma_1,r_T/\sigma_1\right)\right)\cdot$$

$$\cdot\frac{r_1r_2}{\sigma_2^4(1-\rho_2^2)}e^{-\frac{r_1^2+r_2^2+2A_2^2(1-\rho_2)}{2\sigma_2^2(1-\rho_2^2)}}\sum_{i=0}^{\infty}\varepsilon_iI_i\left(\frac{\rho r_1r_2}{\sigma_2^2(1-\rho_2^2)}\right)I_i\left(\frac{A_2r_1}{\sigma_2^2(1+\rho_2)}\right)I_i\left(\frac{A_2r_2}{\sigma_2^2(1+\rho_2)}\right)+$$

$$+P_1\left[\frac{1}{\sigma_2^2}e^{-\frac{A_2^2}{\sigma_2^2(1+\rho_2)}}\sum_{i,l_1,l_2,l_3=0}^{\infty}\varepsilon_i\cdot\frac{1}{l_1!l_2!l_3!(i+l_1)!(i+l_2)!(i+l_3)!}\frac{\rho_2^{i+2l_1}}{\left(2\sigma_2^2(1-\rho_2^2)\right)^{2i+l_1+l_2+2l_3}}\cdot\right.$$

$$\left.\cdot A_2^{2i+2l_2+2l_3}(1-\rho_2)^{2i+2l_2+2l_3}\cdot r_1^{2i+2l_1+2l_3+1}e^{-\frac{r_1^2}{2\sigma_2^2(1-\rho_2^2)}}\gamma\left(i+l_1+l_2+1,\frac{r_T^2}{2\sigma_2^2(1-\rho_2^2)}\right)\right]\cdot$$

$$\cdot\left[\frac{1}{\sigma_1^2}e^{-\frac{A_1^2}{\sigma_1^2(1+\rho_1)}}\sum_{i,l_1,l_2,l_3=0}^{\infty}\varepsilon_i\cdot\frac{1}{l_1!l_2!l_3!(i+l_1)!(i+l_2)!(i+l_3)!}\frac{\rho_1^{i+2l_1}}{\left(2\sigma_1^2(1-\rho_1^2)\right)^{2i+l_1+l_2+2l_3}}\cdot\right.$$

$$\cdot A_1^{2i+2l_2+2l_3}(1-\rho_1)^{2i+2l_2+2l_3}\cdot r_2^{2i+2l_1+2l_3+1}e^{-\frac{r_2^2}{2\sigma_1^2(1-\rho_1^2)}}\gamma\left(i+l_1+l_2+1,\frac{r_T^2}{2\sigma_1^2(1-\rho_1^2)}\right)\Bigg]+$$

$$+P_2\left(1-Q_1\left(A/\sigma_2,r_T/\sigma_2\right)\right)\cdot$$

$$\cdot\frac{r_1r_2}{\sigma_1^4(1-\rho_1^2)}e^{-\frac{r_1^2+r_2^2+2A_1^2(1-\rho_1)}{2\sigma_1^2(1-\rho_1^2)}}\sum_{i=0}^{\infty}\varepsilon_iI_i\left(\frac{\rho_1r_1r_2}{\sigma_1^2(1-\rho_1^2)}\right)I_i\left(\frac{A_1r_1}{\sigma_1^2(1+\rho_1)}\right)I_i\left(\frac{A_1r_2}{\sigma_1^2(1+\rho_1)}\right)+$$

$$+P_2\left[\frac{1}{\sigma_1^2}e^{-\frac{A_1^2}{\sigma_1^2(1+\rho_1)}}\sum_{i,l_1,l_2,l_3=0}^{\infty}\varepsilon_i\cdot\frac{1}{l_1!l_2!l_3!(i+l_1)!(i+l_2)!(i+l_3)!}\frac{\rho_1^{i+2l_1}}{\left(2\sigma_1^2(1-\rho_1^2)\right)^{2i+l_1+l_2+2l_3}}\cdot\right.$$

$$\left.\cdot A_1^{2i+2l_2+2l_3}(1-\rho_1)^{2i+2l_2+2l_3}\cdot r_1^{2i+2l_1+2l_3+1}e^{-\frac{r_1^2}{2\sigma_1^2(1-\rho_1^2)}}\gamma\left(i+l_1+l_2+1,\frac{r_T^2}{2\sigma_1^2(1-\rho_1^2)}\right)\right]\cdot$$

$$\cdot\left[\frac{1}{\sigma_2^2}e^{-\frac{A_2^2}{\sigma_2^2(1+\rho_2)}}\sum_{i,l_1,l_2,l_3=0}^{\infty}\varepsilon_i\cdot\frac{1}{l_1!l_2!l_3!(i+l_1)!(i+l_2)!(i+l_3)!}\frac{\rho_2^{i+2l_1}}{\left(2\sigma_2^2(1-\rho_2^2)\right)^{2i+l_1+l_2+2l_3}}\cdot\right.$$

$$\left.\cdot A_2^{2i+2l_2+2l_3}(1-\rho_2)^{2i+2l_2+2l_3}\cdot r_2^{2i+2l_1+2l_3+1}e^{-\frac{r_2^2}{2\sigma_2^2(1-\rho_2^2)}}\gamma\left(i+l_1+l_2+1,\frac{r_T^2}{2\sigma_2^2(1-\rho_2^2)}\right)\right]\quad(3.5.20)$$

Za $r_1\geq r_T$, $r_2\geq r_T$

$$p_{r_1r_2}(r_1,r_2)=P_1\frac{r_1r_2}{\sigma_1^4(1-\rho_1^2)}e^{-\frac{r_1^2+r_2^2+2A_1^2(1-\rho_1)}{2\sigma_1^2(1-\rho_1^2)}}\sum_{i=0}^{\infty}\varepsilon_iI_i\left(\frac{\rho_1r_1r_2}{\sigma_1^2(1-\rho_1^2)}\right)I_i\left(\frac{A_1r_1}{\sigma_1^2(1+\rho_1)}\right)I_i\left(\frac{A_1r_2}{\sigma_1^2(1+\rho_1)}\right)+$$

$$+P_1\frac{r_2}{\sigma_2^2}e^{-\frac{r_2^2+A_2^2}{2\sigma_2^2}}I_0\left(\frac{r_2A_2}{\sigma_2^2}\right)\cdot$$

$$\cdot\left[\frac{1}{\sigma_1^2}e^{-\frac{A_1^2}{\sigma_1^2(1+\rho_1)}}\sum_{i,l_1,l_2,l_3=0}^{\infty}\varepsilon_i\cdot\frac{1}{l_1!l_2!l_3!(i+l_1)!(i+l_2)!(i+l_3)!}\frac{\rho_1^{i+2l_1}}{\left(2\sigma_1^2(1-\rho_1^2)\right)^{2i+l_1+l_2+2l_3}}\cdot\right.$$

$$\left.\cdot A_1^{2i+2l_2+2l_3}(1-\rho_1)^{2i+2l_2+2l_3}\cdot r_1^{2i+2l_1+2l_3+1}e^{-\frac{r_1^2}{2\sigma_1^2(1-\rho_1^2)}}\gamma\left(i+l_1+l_2+1,\frac{r_T^2}{2\sigma_1^2(1-\rho_1^2)}\right)\right]+$$

$$+P_1\left(1-Q_1\left(A/\sigma_1,r_T/\sigma_1\right)\right)\cdot$$

$$\cdot\frac{r_1r_2}{\sigma_2^4(1-\rho_1^2)}e^{-\frac{r_1^2+r_2^2+2A_2^2(1-\rho_1)}{2\sigma_2^2(1-\rho_1^2)}}\sum_{i=0}^{\infty}\varepsilon_iI_i\left(\frac{\rho_1r_1r_2}{\sigma_2^2(1-\rho_1^2)}\right)I_i\left(\frac{A_2r_1}{\sigma_2^2(1+\rho_1)}\right)I_i\left(\frac{A_2r_2}{\sigma_2^2(1+\rho_1)}\right)+$$

$$+P_1\left[\frac{1}{\sigma_2{}^2}e^{-\frac{A_2{}^2}{\sigma_2{}^2(1+\rho_2)}}\sum_{i,l_1,l_2,l_3=0}^{\infty}\varepsilon_i\cdot\frac{1}{l_1!l_2!l_3!(i+l_1)!(i+l_2)!(i+l_3)!}\frac{\rho_2{}^{i+2l_1}}{\left(2\sigma_2{}^2(1-\rho_2{}^2)\right)^{2i+l_1+l_2+2l_3}}\cdot\right.$$

$$\left.\cdot A_2{}^{2i+2l_2+2l_3}(1-\rho_2)^{2i+2l_2+2l_3}\cdot r_1{}^{2i+2l_1+2l_3+1}e^{-\frac{r_1{}^2}{2\sigma_2{}^2(1-\rho_2{}^2)}}\gamma\left(i+l_1+l_2+1,\frac{r_T{}^2}{2\sigma_2{}^2(1-\rho_2{}^2)}\right)\right]\cdot$$

$$\cdot\left[\frac{1}{\sigma_1{}^2}e^{-\frac{A_1{}^2}{\sigma_1{}^2(1+\rho_1)}}\sum_{i,l_1,l_2,l_3=0}^{\infty}\varepsilon_i\cdot\frac{1}{l_1!l_2!l_3!(i+l_1)!(i+l_2)!(i+l_3)!}\frac{\rho_1{}^{i+2l_1}}{\left(2\sigma_1{}^2(1-\rho_1{}^2)\right)^{2i+l_1+l_2+2l_3}}\cdot\right.$$

$$\left.\cdot A_1{}^{2i+2l_2+2l_3}(1-\rho_1)^{2i+2l_2+2l_3}\cdot r_2{}^{2i+2l_1+2l_3+1}e^{-\frac{r_2{}^2}{2\sigma_1{}^2(1-\rho_1{}^2)}}\gamma\left(i+l_1+l_2+1,\frac{r_T{}^2}{2\sigma_1{}^2(1-\rho_1{}^2)}\right)\right]+$$

$$+P_2\frac{r_1r_2}{\sigma_2{}^4(1-\rho_2{}^2)}e^{-\frac{r_1{}^2+r_2{}^2+2A_2{}^2(1-\rho_2)}{2\sigma_2{}^2(1-\rho_2{}^2)}}\sum_{i=0}^{\infty}\varepsilon_iI_i\left(\frac{\rho_2r_1r_2}{\sigma_2{}^2(1-\rho_2{}^2)}\right)I_i\left(\frac{A_2r_1}{\sigma_2{}^2(1+\rho_2)}\right)I_i\left(\frac{A_2r_2}{\sigma_2{}^2(1+\rho_2)}\right)+$$

$$+P_2\frac{r_2}{\sigma_1{}^2}e^{-\frac{r_2{}^2+A_1{}^2}{2\sigma_1{}^2}}I_0\left(\frac{r_2A_1}{\sigma_1{}^2}\right)\cdot$$

$$\cdot\left[\frac{1}{\sigma_2{}^2}e^{-\frac{A_2{}^2}{\sigma_2{}^2(1+\rho_2)}}\sum_{i,l_1,l_2,l_3=0}^{\infty}\varepsilon_i\cdot\frac{1}{l_1!l_2!l_3!(i+l_1)!(i+l_2)!(i+l_3)!}\frac{\rho_2{}^{i+2l_1}}{\left(2\sigma_2{}^2(1-\rho_2{}^2)\right)^{2i+l_1+l_2+2l_3}}\cdot\cdot\right.$$

$$\left.\cdot A_2{}^{2i+2l_2+2l_3}(1-\rho_2)^{2i+2l_2+2l_3}\cdot r_1{}^{2i+2l_1+2l_3+1}e^{-\frac{r_1{}^2}{2\sigma_2{}^2(1-\rho_2{}^2)}}\gamma\left(i+l_1+l_2+1,\frac{r_T{}^2}{2\sigma_2{}^2(1-\rho_2{}^2)}\right)\right]\cdot$$

$$+P_2\left(1-Q_1\left(A/\sigma_2,r_T/\sigma_2\right)\right)\cdot$$

$$\cdot\frac{r_1r_2}{\sigma_1{}^4(1-\rho_1{}^2)}e^{-\frac{r_1{}^2+r_2{}^2+2A_1{}^2(1-\rho_1)}{2\sigma_1{}^2(1-\rho_1{}^2)}}\sum_{i=0}^{\infty}\varepsilon_iI_i\left(\frac{\rho_1r_1r_2}{\sigma_1{}^2(1-\rho_1{}^2)}\right)I_i\left(\frac{A_1r_1}{\sigma_1{}^2(1+\rho_1)}\right)I_i\left(\frac{A_1r_2}{\sigma_1{}^2(1+\rho_1)}\right)+$$

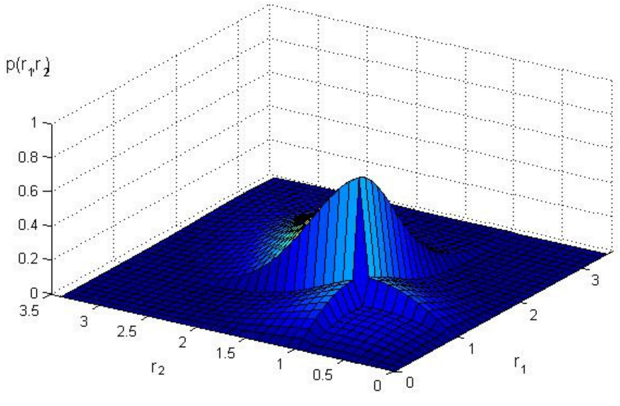
$$+P_2\left[\frac{1}{\sigma_1{}^2}e^{-\frac{A_1{}^2}{\sigma_1{}^2(1+\rho_1)}}\sum_{i,l_1,l_2,l_3=0}^{\infty}\varepsilon_i\cdot\frac{1}{l_1!l_2!l_3!(i+l_1)!(i+l_2)!(i+l_3)!}\frac{\rho_1{}^{i+2l_1}}{\left(2\sigma_1{}^2(1-\rho_1{}^2)\right)^{2i+l_1+l_2+2l_3}}\cdot\right.$$

$$\left.\cdot A_1{}^{2i+2l_2+2l_3}(1-\rho_1)^{2i+2l_2+2l_3}\cdot r_1{}^{2i+2l_1+2l_3+1}e^{-\frac{r_1{}^2}{2\sigma_1{}^2(1-\rho_1{}^2)}}\gamma\left(i+l_1+l_2+1,\frac{r_T{}^2}{2\sigma_1{}^2(1-\rho_1{}^2)}\right)\right]\cdot$$

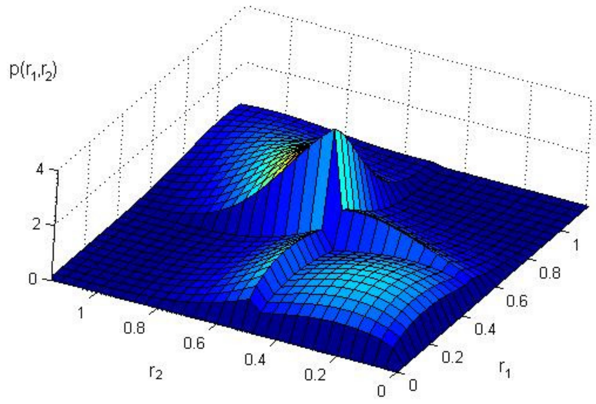
$$\cdot\left[\frac{1}{\sigma_2{}^2}e^{-\frac{A_2{}^2}{\sigma_2{}^2(1+\rho_2)}}\sum_{i,l_1,l_2,l_3=0}^{\infty}\varepsilon_i\cdot\frac{1}{l_1!l_2!l_3!(i+l_1)!(i+l_2)!(i+l_3)!}\frac{\rho_2{}^{i+2l_1}}{\left(2\sigma_2{}^2(1-\rho_2{}^2)\right)^{2i+l_1+l_2+2l_3}}\cdot\right.$$

$$\cdot A_2^{\,2i+2l_2+2l_3}(1-\rho_2)^{2i+2l_2+2l_3}\cdot r_2^{\,2i+2l_1+2l_3+1}e^{-\frac{r_2^{\,2}}{2\sigma_2^{\,2}(1-\rho_2^{\,2})}}\gamma\left(i+l_1+l_2+1,\frac{r_T^{\,2}}{2\sigma_2^{\,2}(1-\rho_2^{\,2})}\right)\Bigg] \quad (3.5.21)$$

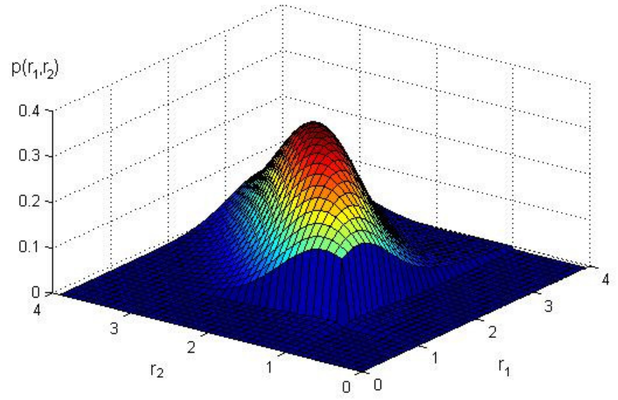
Na slikama 3.5.1.-9. predstavljena je zavisnost PDF od vrednosti signala za različite vrednosti parametara raspodele, korelacije i praga odlučivanja. Radi uproštavanje, a ne gubeći uopštenost, pretpostavljeno je da su parametri raspodele isti za obe grane kombinera



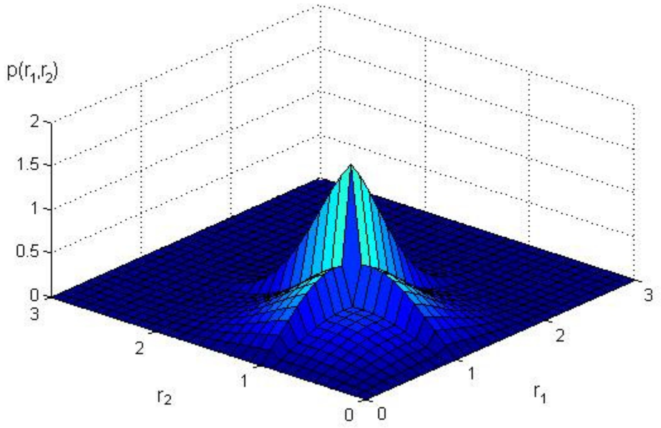
Slika 3.5.1. Združena gustina raspodele verovatnoće na izlazu iz SSC kombinera u dva trenutka vremena u prisustvu Rice-ovog fedinga za parametre: $\rho = 0.8$, $r_T = 0.5$, $\sigma = 1$, $A = 0.5$



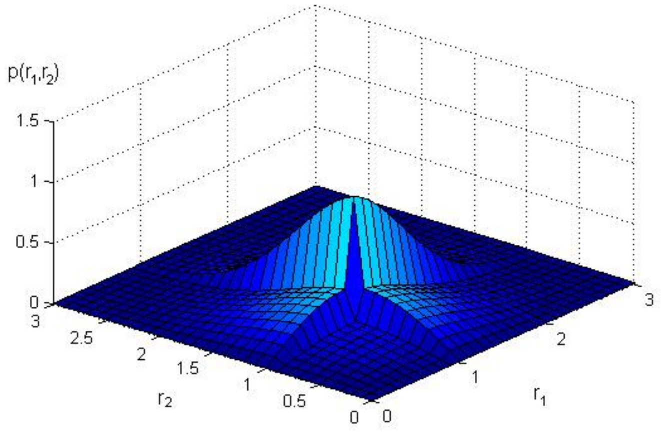
Slika 3.5.2. Združena gustina raspodele verovatnoće na izlazu iz SSC kombinera u dva trenutka vremena u prisustvu Rice-ovog fedinga za parametre: $\rho = 0.8$, $r_T = 0.5$, $\sigma = 1$, $A = 1$



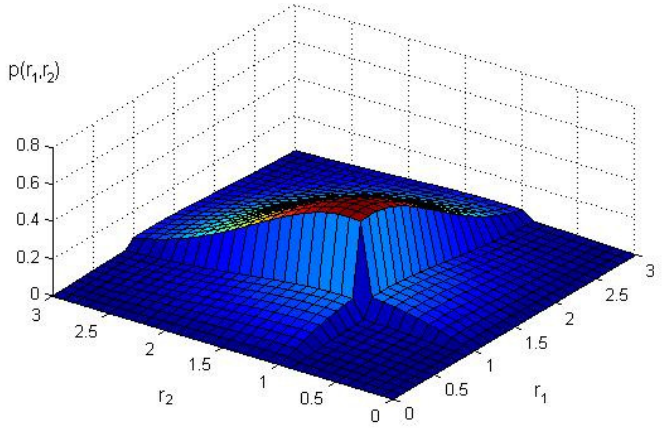
Slika 3.5.3. Združena gustina raspodele verovatnoće na izlazu iz SSC kombinera u dva trenutka vremena u prisustvu Rice-ovog fedinga za parametre: $\rho = 0.8$, $r_T = 0.5$, $\sigma = 1$, $A = 2$



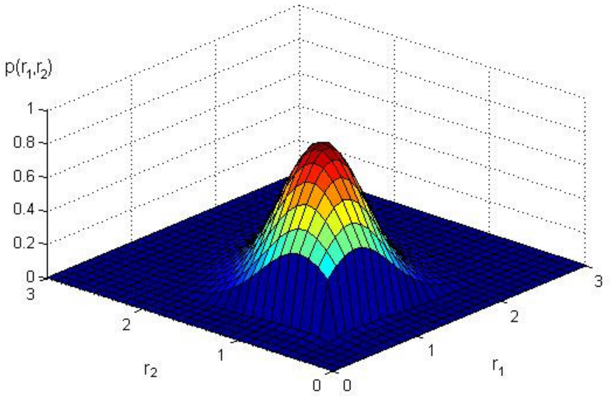
Slika 3.5.4. Združena gustina raspodele verovatnoće na izlazu iz SSC kombinera u dva trenutka vremena u prisustvu Rice-ovog fedinga za parametre: $\rho = 0.1$, $r_T = 1$, $A = 0.7$, $\sigma = 0.5$



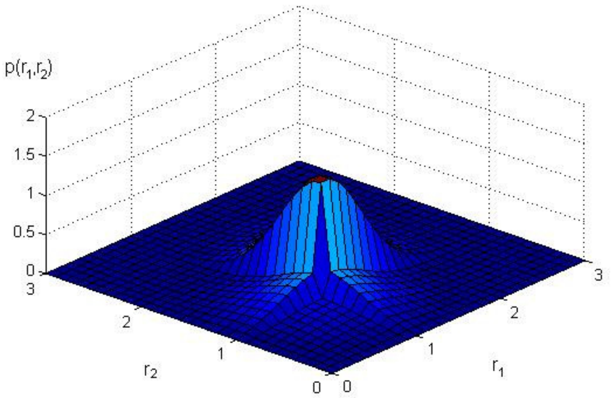
Slika 3.5.5. Združena gustina raspodele verovatnoće na izlazu iz SSC kombinera u dva trenutka vremena u prisustvu Rice-ovog fedinga za parametre: $\rho = 0.1$, $r_T = 1$, $A = 0.7$, $\sigma = 0.7$



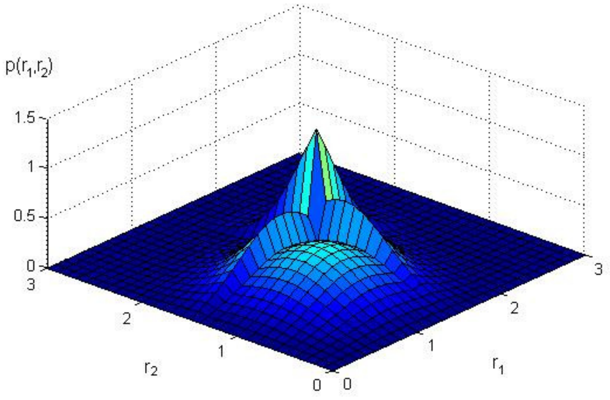
Slika 3.5.6. Združena gustina raspodele verovatnoće na izlazu iz SSC kombinera u dva trenutka vremena u prisustvu Rice-ovog fedinga za parametre: $\rho = 0.1$, $r_T = 1$, $A = 0.7$, $\sigma = 1$



Slika 3.5.7. Združena gustina raspodele verovatnoće na izlazu iz SSC kombinera u dva trenutka vremena u prisustvu Rice-ovog fedinga za parametre: $\rho = 0.5$, $A = 1$, $\sigma = 0.5$, $r_T = 0.5$



Slika 3.5.9. Združena gustina raspodele verovatnoće na izlazu iz SSC kombinera u dva trenutka vremena u prisustvu Rice-ovog fedinga za parametre: $\rho = 0.5$, $A = 1$, $\sigma = 0.5$, $r_T = 1$



Slika 3.5.9. Združena gustina raspodele verovatnoće na izlazu iz SSC kombinera u dva trenutka vremena u prisustvu Rice-ovog fedinga za parametre: $\rho = 0.5$, $A = 1$, $\sigma = 0.5$, $r_T = 1.5$

3.6 Združena gustina raspodele verovatnoće na izlazu SSC kombinera u dva trenutka vremena u prisustvu Weibull-ovog fedinga

Gustina raspodele verovatnoće i kumulativna raspodela verovatnoće (CDF) signala na izlazu iz kombinera $r_{i,j}$ u prisustvu Weibull -ovog fedinga su [13], [8]:

$$p_{r_i}(r_{i,j}) = \frac{\beta_i}{\Omega_i} r_{i,j}^{\beta_i - 1} e^{-\frac{r_{i,j}^{\beta_i}}{\Omega_i}} \quad , \quad r_{i,j} \geq 0 \tag{3.6.1}$$

$$F_{r_i}(r_{i,j}) = 1 - e^{-\frac{r_{i,j}^{\beta_i}}{\Omega_i}} \quad , \quad r_{i,j} \geq 0 \tag{3.6.2}$$

gde su $i=1,2$ $j=1,2$, β_i predstavlja Weibull-ov feding parametar i pozitivna je realna konstanta i $\Omega_i = E\left(r_{i,j}^{\beta_i}\right)$.

Verovatnoće P_1 i P_2 se dobijaju ako se u (3.1.17-18) stavi (3.6.2):

$$P_1 = \frac{F_{r_2}(r_T)}{F_{r_1}(r_T) + F_{r_2}(r_T)} = \frac{1 - e^{-\frac{r_T^{\beta_2}}{\Omega_2}}}{e^{-\frac{r_T^{\beta_1}}{\Omega_1}} + e^{-\frac{r_T^{\beta_2}}{\Omega_2}}} \tag{3.6.3}$$

$$P_2 = \frac{F_{r_1}(r_T)}{F_{r_1}(r_T) + F_{r_2}(r_T)} = \frac{1 - e^{-\frac{r_T^{\beta_1}}{\Omega_1}}}{e^{-\frac{r_T^{\beta_1}}{\Omega_1}} + e^{-\frac{r_T^{\beta_2}}{\Omega_2}}} \tag{3.6.4}$$

Združena gustina raspodele verovatnoće korelisanih signala x_1 i x_2 sa Weibull-ovom raspodelom i istim parametrima raspodele je [8]:

$$p_{x_1x_2}(x_1,x_2)=\frac{\beta^2(x_1x_2)^{\beta-1}}{\Omega^2(1-\rho)}\exp\left[-\frac{1}{1-\rho}\left(\frac{x_1{}^{\beta}}{\Omega}+\frac{x_2{}^{\beta}}{\Omega}\right)\right]I_0\left[\frac{2\sqrt{\rho}\,x_1{}^{\beta/2}x_2{}^{\beta/2}}{(1-\rho)\Omega}\right] \tag{3.6.5}$$

gde je ρ koeficijent korelacije, $I_i(\ )$ je modifikovana Bessel-ova funkcija prve vrste i-tog reda (3.3.20), [51].

Združena gustina raspodele verovatnoće signala r_1 i r_2 na izlazu SSC kombinera u dva trenutka vremena u prisustvu Weibull-ovog fedinga kada su signali na ulazu u grane kombinera nezavisni, može se dobiti ako se u (3.2.5-8) stave izrazi (3.3.55) i (3.3.59)

Za $r_1<r_T$, $r_2<r_T$

$$\begin{aligned}
p_{r_1r_2}(r_1,r_2)={}&P_1\int_0^{r_T}\frac{\beta_1{}^2(r_{11}r_2)^{\beta_1-1}}{\Omega_1{}^2(1-\rho_1)}e^{-\frac{1}{1-\rho_1}\left(\frac{r_{11}{}^{\beta_1}}{\Omega_1}+\frac{r_2{}^{\beta_1}}{\Omega_1}\right)}I_0\left[\frac{2\sqrt{\rho_1}r_{11}{}^{\beta_1/2}r_2{}^{\beta_1/2}}{(1-\rho_1)\Omega_1}\right]dr_{11}\cdot\\
&\cdot\int_0^{r_T}\frac{\beta_2{}^2(r_{22}r_1)^{\beta_1-1}}{\Omega_2{}^2(1-\rho_2)}e^{-\frac{1}{1-\rho_2}\left(\frac{r_{22}{}^{\beta_2}}{\Omega_2}+\frac{r_1{}^{\beta_2}}{\Omega_2}\right)}I_0\left[\frac{2\sqrt{\rho_2}r_{22}{}^{\beta_2/2}r_1{}^{\beta_2/2}}{(1-\rho_2)\Omega_2}\right]dr_{22}+\\
&+P_2\int_0^{r_T}\frac{\beta_2{}^2(r_{21}r_2)^{\beta_1-1}}{\Omega_2{}^2(1-\rho_2)}e^{-\frac{1}{1-\rho_2}\left(\frac{r_{21}{}^{\beta_2}}{\Omega_2}+\frac{r_2{}^{\beta_2}}{\Omega_2}\right)}I_0\left[\frac{2\sqrt{\rho_2}r_{21}{}^{\beta_2/2}r_2{}^{\beta_2/2}}{(1-\rho_2)\Omega_2}\right]dr_{21}\cdot\\
&\cdot\int_0^{r_T}\frac{\beta_1{}^2(r_{12}r_1)^{\beta_1-1}}{\Omega_1{}^2(1-\rho_1)}e^{-\frac{1}{1-\rho_1}\left(\frac{r_{12}{}^{\beta_1}}{\Omega_1}+\frac{r_1{}^{\beta_1}}{\Omega_1}\right)}I_0\left[\frac{2\sqrt{\rho_1}r_{12}{}^{\beta_1/2}r_1{}^{\beta_1/2}}{(1-\rho_1)\Omega_1}\right]dr_{12}
\end{aligned} \tag{3.6.6}$$

Za $r_1\geq r_T$, $r_2<r_T$

$$\begin{aligned}
p_{r_1r_2}(r_1,r_2)={}&P_1\frac{\beta_2}{\Omega_2}r_2{}^{\beta_2-1}e^{-\frac{r_2{}^{\beta_2}}{\Omega_2}}\int_0^{r_T}\frac{\beta_1{}^2(r_{12}r_1)^{\beta_1-1}}{\Omega_1{}^2(1-\rho_1)}e^{-\frac{1}{1-\rho_1}\left(\frac{r_{12}{}^{\beta_1}}{\Omega_1}+\frac{r_1{}^{\beta_1}}{\Omega_1}\right)}I_0\left[\frac{2\sqrt{\rho_1}r_{12}{}^{\beta_1/2}r_1{}^{\beta_1/2}}{(1-\rho_1)\Omega_1}\right]dr_{12}+\\
&+P_1\int_0^{r_T}\frac{\beta_1{}^2(r_{11}r_2)^{\beta_1-1}}{\Omega_1{}^2(1-\rho_1)}e^{-\frac{1}{1-\rho_1}\left(\frac{r_{11}{}^{\beta_1}}{\Omega_1}+\frac{r_2{}^{\beta_1}}{\Omega_1}\right)}I_0\left[\frac{2\sqrt{\rho_1}r_{11}{}^{\beta_1/2}r_2{}^{\beta_1/2}}{(1-\rho_1)\Omega_1}\right]dr_{11}\cdot\\
&\cdot\int_0^{r_T}\frac{\beta_2{}^2(r_{22}r_1)^{\beta_1-1}}{\Omega_2{}^2(1-\rho_2)}e^{-\frac{1}{1-\rho_2}\left(\frac{r_{22}{}^{\beta_2}}{\Omega_2}+\frac{r_1{}^{\beta_2}}{\Omega_2}\right)}I_0\left[\frac{2\sqrt{\rho_2}r_{22}{}^{\beta_2/2}r_1{}^{\beta_2/2}}{(1-\rho_2)\Omega_2}\right]dr_{22}+\\
&+P_2\frac{\beta_1}{\Omega_1}r_2{}^{\beta_1-1}e^{-\frac{r_2{}^{\beta_1}}{\Omega_1}}\int_0^{r_T}\frac{\beta_2{}^2(r_{22}r_1)^{\beta_1-1}}{\Omega_2{}^2(1-\rho_2)}e^{-\frac{1}{1-\rho_2}\left(\frac{r_{22}{}^{\beta_2}}{\Omega_2}+\frac{r_1{}^{\beta_2}}{\Omega_2}\right)}I_0\left[\frac{2\sqrt{\rho_2}r_{22}{}^{\beta_2/2}r_1{}^{\beta_2/2}}{(1-\rho_2)\Omega_2}\right]dr_{22}+
\end{aligned}$$

$$+P_2\int_0^{r_T}\frac{\beta_2^{\,2}\left(r_{21}r_2\right)^{\beta_1-1}}{\Omega_2^{\,2}\left(1-\rho_2\right)}e^{-\frac{1}{1-\rho_2}\left(\frac{r_{21}^{\,\beta_2}}{\Omega_2}+\frac{r_2^{\,\beta_2}}{\Omega_2}\right)}I_0\left[\frac{2\sqrt{\rho_2}\,r_{21}^{\,\beta_2/2}r_2^{\,\beta_2/2}}{\left(1-\rho_2\right)\Omega_2}\right]dr_{21}\cdot$$

$$\cdot\int_0^{r_T}\frac{\beta_1^{\,2}\left(r_{12}r_1\right)^{\beta_1-1}}{\Omega_1^{\,2}\left(1-\rho_1\right)}e^{-\frac{1}{1-\rho_1}\left(\frac{r_{12}^{\,\beta_1}}{\Omega_1}+\frac{r_1^{\,\beta_1}}{\Omega_1}\right)}I_0\left[\frac{2\sqrt{\rho_1}\,r_{12}^{\,\beta_1/2}r_1^{\,\beta_1/2}}{\left(1-\rho_1\right)\Omega_1}\right]dr_{12} \tag{3.6.7}$$

Za $r_1<r_T$, $r_2\geq r_T$

$$p_{r_1r_2}(r_1,r_2)=P_1\left(1-e^{-\frac{r_T^{\,\beta_1}}{\Omega_1}}\right)\frac{\beta_2^{\,2}\left(r_1r_2\right)^{\beta_1-1}}{\Omega_2^{\,2}\left(1-\rho_2\right)}e^{-\frac{1}{1-\rho_2}\left(\frac{r_1^{\,\beta_2}}{\Omega_2}+\frac{r_2^{\,\beta_2}}{\Omega_2}\right)}I_0\left[\frac{2\sqrt{\rho_2}\,r_1^{\,\beta_2/2}r_2^{\,\beta_2/2}}{\left(1-\rho_2\right)\Omega_2}\right]+$$

$$+P_1\int_0^{r_T}\frac{\beta_1^{\,2}\left(r_{11}r_2\right)^{\beta_1-1}}{\Omega_1^{\,2}\left(1-\rho_1\right)}e^{-\frac{1}{1-\rho_1}\left(\frac{r_{11}^{\,\beta_1}}{\Omega_1}+\frac{r_2^{\,\beta_1}}{\Omega_1}\right)}I_0\left[\frac{2\sqrt{\rho_1}\,r_{11}^{\,\beta_1/2}r_2^{\,\beta_1/2}}{\left(1-\rho_1\right)\Omega_1}\right]dr_{11}\cdot$$

$$\cdot\int_0^{r_T}\frac{\beta_2^{\,2}\left(r_{22}r_1\right)^{\beta_1-1}}{\Omega_2^{\,2}\left(1-\rho_2\right)}e^{-\frac{1}{1-\rho_2}\left(\frac{r_{22}^{\,\beta_2}}{\Omega_2}+\frac{r_1^{\,\beta_2}}{\Omega_2}\right)}I_0\left[\frac{2\sqrt{\rho_2}\,r_{22}^{\,\beta_2/2}r_1^{\,\beta_2/2}}{\left(1-\rho_2\right)\Omega_2}\right]dr_{22}+$$

$$+P_2\left(1-e^{-\frac{r_T^{\,\beta_2}}{\Omega_2}}\right)\frac{\beta_1^{\,2}\left(r_1r_2\right)^{\beta_1-1}}{\Omega_1^{\,2}\left(1-\rho_1\right)}e^{-\frac{1}{1-\rho_1}\left(\frac{r_1^{\,\beta_1}}{\Omega_1}+\frac{r_2^{\,\beta_1}}{\Omega_1}\right)}I_0\left[\frac{2\sqrt{\rho_1}\,r_1^{\,\beta_1/2}r_2^{\,\beta_1/2}}{\left(1-\rho_1\right)\Omega_1}\right]+$$

$$+P_2\int_0^{r_T}\frac{\beta_2^{\,2}\left(r_{21}r_2\right)^{\beta_1-1}}{\Omega_2^{\,2}\left(1-\rho_2\right)}e^{-\frac{1}{1-\rho_2}\left(\frac{r_{21}^{\,\beta_2}}{\Omega_2}+\frac{r_2^{\,\beta_2}}{\Omega_2}\right)}I_0\left[\frac{2\sqrt{\rho_2}\,r_{21}^{\,\beta_2/2}r_2^{\,\beta_2/2}}{\left(1-\rho_2\right)\Omega_2}\right]dr_{21}\cdot$$

$$\cdot\int_0^{r_T}\frac{\beta_1^{\,2}\left(r_{12}r_1\right)^{\beta_1-1}}{\Omega_1^{\,2}\left(1-\rho_1\right)}e^{-\frac{1}{1-\rho_1}\left(\frac{r_{12}^{\,\beta_1}}{\Omega_1}+\frac{r_1^{\,\beta_1}}{\Omega_1}\right)}I_0\left[\frac{2\sqrt{\rho_1}\,r_{12}^{\,\beta_1/2}r_1^{\,\beta_1/2}}{\left(1-\rho_1\right)\Omega_1}\right]dr_{12} \tag{3.6.8}$$

Za $r_1\geq r_T$, $r_2\geq r_T$

$$p_{r_1r_2}(r_1,r_2)=P_1\frac{\beta_1^{\,2}\left(r_1r_2\right)^{\beta_1-1}}{\Omega_1^{\,2}\left(1-\rho_1\right)}e^{-\frac{1}{1-\rho_1}\left(\frac{r_1^{\,\beta_1}}{\Omega_1}+\frac{r_2^{\,\beta_1}}{\Omega_1}\right)}I_0\left[\frac{2\sqrt{\rho_1}\,r_1^{\,\beta_1/2}r_2^{\,\beta_1/2}}{\left(1-\rho_1\right)\Omega_1}\right]+$$

$$+P_1\frac{\beta_2}{\Omega_2}r_2^{\,\beta_2-1}e^{-\frac{r_2^{\,\beta_2}}{\Omega_2}}\int_0^{r_T}\frac{\beta_1^{\,2}\left(r_{12}r_1\right)^{\beta_1-1}}{\Omega_1^{\,2}\left(1-\rho_1\right)}e^{-\frac{1}{1-\rho_1}\left(\frac{r_{12}^{\,\beta_1}}{\Omega_1}+\frac{r_1^{\,\beta_1}}{\Omega_1}\right)}I_0\left[\frac{2\sqrt{\rho_1}\,r_{12}^{\,\beta_1/2}r_1^{\,\beta_1/2}}{\left(1-\rho_1\right)\Omega_1}\right]dr_{12}+$$

$$+P_1\left(1-e^{-\frac{r_T^{\,\beta_1}}{\Omega_1}}\right)\frac{\beta_2^{\,2}\left(r_1r_2\right)^{\beta_1-1}}{\Omega_2^{\,2}\left(1-\rho_2\right)}e^{-\frac{1}{1-\rho_2}\left(\frac{r_1^{\,\beta_2}}{\Omega_2}+\frac{r_2^{\,\beta_2}}{\Omega_2}\right)}I_0\left[\frac{2\sqrt{\rho_2}\,r_1^{\,\beta_2/2}r_2^{\,\beta_2/2}}{\left(1-\rho_2\right)\Omega_2}\right]+$$

$$+P_1\int_0^{r_T}\frac{\beta_1^{\,2}\left(r_{11}r_2\right)^{\beta_1-1}}{\Omega_1^{\,2}\left(1-\rho_1\right)}e^{-\frac{1}{1-\rho_1}\left(\frac{r_{11}^{\,\beta_1}}{\Omega_1}+\frac{r_2^{\,\beta_1}}{\Omega_1}\right)}I_0\left[\frac{2\sqrt{\rho_1}\,r_{11}^{\,\beta_1/2}r_2^{\,\beta_1/2}}{\left(1-\rho_1\right)\Omega_1}\right]dr_{11}\cdot$$

$$\cdot\int_0^{r_T}\frac{\beta_2{}^2\left(r_{22}r_1\right)^{\beta_1-1}}{\Omega_2{}^2\left(1-\rho_2\right)}e^{-\frac{1}{1-\rho_2}\left(\frac{r_{22}{}^{\beta_2}}{\Omega_2}+\frac{r_1{}^{\beta_2}}{\Omega_2}\right)}I_0\left[\frac{2\sqrt{\rho_2}\,r_{22}{}^{\beta_2/2}r_1{}^{\beta_2/2}}{\left(1-\rho_2\right)\Omega_2}\right]dr_{22}+$$

$$+P_2\frac{\beta_1{}^2\left(r_1r_2\right)^{\beta_1-1}}{\Omega_1{}^2\left(1-\rho_1\right)}e^{-\frac{1}{1-\rho_1}\left(\frac{r_1{}^{\beta_1}}{\Omega_1}+\frac{r_2{}^{\beta_1}}{\Omega_1}\right)}I_0\left[\frac{2\sqrt{\rho_1}\,r_1{}^{\beta_1/2}r_2{}^{\beta_1/2}}{\left(1-\rho_1\right)\Omega_1}\right]+$$

$$+P_2\frac{\beta_1}{\Omega_1}r_2{}^{\beta_1-1}e^{-\frac{r_2{}^{\beta_1}}{\Omega_1}}\int_0^{r_T}\frac{\beta_2{}^2\left(r_{22}r_1\right)^{\beta_1-1}}{\Omega_2{}^2\left(1-\rho_2\right)}e^{-\frac{1}{1-\rho_2}\left(\frac{r_{22}{}^{\beta_2}}{\Omega_2}+\frac{r_1{}^{\beta_2}}{\Omega_2}\right)}I_0\left[\frac{2\sqrt{\rho_2}\,r_{22}{}^{\beta_2/2}r_1{}^{\beta_2/2}}{\left(1-\rho_2\right)\Omega_2}\right]dr_{22}+$$

$$+P_2\left(1-e^{-\frac{r_T{}^{\beta_2}}{\Omega_2}}\right)\frac{\beta_1{}^2\left(r_1r_2\right)^{\beta_1-1}}{\Omega_1{}^2\left(1-\rho_1\right)}e^{-\frac{1}{1-\rho_1}\left(\frac{r_1{}^{\beta_1}}{\Omega_1}+\frac{r_2{}^{\beta_1}}{\Omega_1}\right)}I_0\left[\frac{2\sqrt{\rho_1}\,r_1{}^{\beta_1/2}r_2{}^{\beta_1/2}}{\left(1-\rho_1\right)\Omega_1}\right]+$$

$$+P_2\int_0^{r_T}\frac{\beta_2{}^2\left(r_{21}r_2\right)^{\beta_1-1}}{\Omega_2{}^2\left(1-\rho_2\right)}e^{-\frac{1}{1-\rho_2}\left(\frac{r_{21}{}^{\beta_2}}{\Omega_2}+\frac{r_2{}^{\beta_2}}{\Omega_2}\right)}I_0\left[\frac{2\sqrt{\rho_2}\,r_{21}{}^{\beta_2/2}r_2{}^{\beta_2/2}}{\left(1-\rho_2\right)\Omega_2}\right]dr_{21}\cdot$$

$$\cdot\int_0^{r_T}\frac{\beta_1{}^2\left(r_{12}r_1\right)^{\beta_1-1}}{\Omega_1{}^2\left(1-\rho_1\right)}e^{-\frac{1}{1-\rho_1}\left(\frac{r_{12}{}^{\beta_1}}{\Omega_1}+\frac{r_1{}^{\beta_1}}{\Omega_1}\right)}I_0\left[\frac{2\sqrt{\rho_1}\,r_{12}{}^{\beta_1/2}r_1{}^{\beta_1/2}}{\left(1-\rho_1\right)\Omega_1}\right]dr_{12} \tag{3.6.9}$$

Izrazi (3.6.6-9) su u obliku jednostrukog integrala sa konačnim granicama. Združena gustina raspodele verovatnoće se može dobiti u zatvorenom obliku korišćenjem Marcum-ove *Q*-funkcije prvog reda.

Za predstavljanje združene PDF u zatvorenom obliku potrebno je rešiti integral $\int_{r_T}^{\infty}p_{x_1x_2}(x_1,x_2)dx_1$, gde je $p_{x_1x_2}(x_1,x_2)$ dato u (3.3.59). Transformacijom $p_{x_1x_2}(x_1,x_2)$, ona se može predstaviti u obliku koji u podintegralnom delu predstavlja podintegralni deo Marcum-ove *Q*-funkcije prvog reda.

$$x_1=x^{2/\beta}\left(\frac{\Omega(1-\rho)}{2}\right)^{1/\beta}\qquad x=\frac{\sqrt{2}}{\sqrt{\Omega(1-\rho)}}x_1{}^{\beta/2}\qquad dx_1=\left(\frac{\Omega(1-\rho)}{2}\right)^{1/\beta}\frac{2}{\beta}x^{2/\beta-1} \tag{3.6.10}$$

$$x_2=a^{2/\beta}\left(\frac{\Omega(1-\rho)}{2\rho}\right)^{1/\beta}\qquad a=\frac{\sqrt{2\rho}}{\sqrt{\Omega(1-\rho)}}x_2{}^{\beta/2} \tag{3.6.11}$$

$$p_{x_1x_2}(x_1,x_2)=\frac{\beta^2\left(\frac{\Omega(1-\rho)}{2}\right)^{\frac{2(\beta-1)}{\beta}}\rho^{\frac{\beta}{\beta-1}}}{\Omega^2\left(1-\rho\right)}a^{\frac{2(\beta-1)}{\beta}}e^{-\frac{1-\rho}{2\rho}a^2}x^{\frac{2(\beta-1)}{\beta}}e^{-\frac{x^2+a^2}{2}}\cdot I_0\left(xa\right) \tag{3.6.12}$$

$$\int_{r_T}^{\infty} p_{x_1x_2}(x_1,x_2)dx_1 = \frac{\beta^2\left(\frac{\Omega(1-\rho)}{2}\right)^{\frac{2(\beta-1)}{\beta}} \rho^{\frac{\beta}{\beta-1}}}{\Omega^2(1-\rho)} a^{\frac{2\beta-2}{\beta}} e^{-\frac{1-\rho}{2\rho}a^2} \cdot$$

$$\cdot \int_{\frac{\sqrt{2}}{\sqrt{\Omega(1-\rho)}}r_t^{\beta/2}}^{\infty} x^{\frac{2(\beta-1)}{\beta}} e^{-\frac{x^2+a^2}{2}} I_0(ax)\left(\frac{\Omega(1-\rho)}{2}\right)^{1/\beta} \frac{2}{\beta} x^{\frac{2-\beta}{\beta}} dx =$$

$$= \frac{\beta\left(\frac{\Omega(1-\rho)}{2}\right)^{\frac{\beta-1}{\beta}} \rho^{\frac{\beta}{\beta-1}}}{\Omega} a^{\frac{2\beta-2}{\beta}} e^{-\frac{1-\rho}{2\rho}a^2} \int_{\frac{\sqrt{2}}{\sqrt{\Omega(1-\rho)}}r_t^{\beta/2}}^{\infty} x e^{-\frac{x^2+a^2}{2}} I_0(ax)dx =$$

$$= \frac{\beta}{\Omega} x_2^{\beta-1} e^{-\frac{x_2^{\beta}}{\Omega}} Q_1\left(\frac{\sqrt{2\rho}}{\sqrt{\Omega(1-\rho)}} x_2^{\beta/2}, \frac{\sqrt{2}}{\sqrt{\Omega(1-\rho)}} r_t^{\beta/2}\right) \tag{3.6.13}$$

Na osnovu (3.6.13) se dobija:

$$\int_{0}^{r_T} p_{x_1x_2}(x_1,x_2)dx_1 = \frac{\beta}{\Omega} x_2^{\beta-1} e^{-\frac{x_2^{\beta}}{\Omega}} \left[1 - Q_1\left(\frac{\sqrt{2\rho}}{\sqrt{\Omega(1-\rho)}} x_2^{\beta/2}, \frac{\sqrt{2}}{\sqrt{\Omega(1-\rho)}} r_t^{\beta/2}\right)\right] \tag{3.6.14}$$

Zamenom (3.6.14) u izrazima (3.6.6-9) dobija se konačni oblik za združenu gustinu raspodele verovatnoće na izlazu iz SSC kombinera

Za $r_1<r_T$, $r_2<r_T$

$$p_{r_1r_2}(r_1,r_2) = P_1 \frac{\beta_2}{\Omega_2} r_1^{\beta_2-1} e^{-\frac{r_1^{\beta_2}}{\Omega_2}} \left[1 - Q_1\left(\frac{\sqrt{2\rho_2}}{\sqrt{\Omega_2(1-\rho_2)}} r_1^{\beta_2/2}, \frac{\sqrt{2}}{\sqrt{\Omega_2(1-\rho_2)}} r_T^{\beta_2/2}\right)\right] \cdot$$

$$\cdot \frac{\beta_1}{\Omega_1} r_2^{\beta_1-1} e^{-\frac{r_2^{\beta_1}}{\Omega_1}} \left[1 - Q_1\left(\frac{\sqrt{2\rho_1}}{\sqrt{\Omega_1(1-\rho_1)}} r_2^{\beta_1/2}, \frac{\sqrt{2}}{\sqrt{\Omega_1(1-\rho_1)}} r_T^{\beta_1/2}\right)\right] +$$

$$+ P_2 \frac{\beta_1}{\Omega_1} r_1^{\beta_1-1} e^{-\frac{r_1^{\beta_1}}{\Omega_1}} \left[1 - Q_1\left(\frac{\sqrt{2\rho_1}}{\sqrt{\Omega_1(1-\rho_1)}} r_1^{\beta_1/2}, \frac{\sqrt{2}}{\sqrt{\Omega_1(1-\rho_1)}} r_T^{\beta_1/2}\right)\right] \cdot$$

$$\cdot \frac{\beta_2}{\Omega_2} r_2^{\beta_2-1} e^{-\frac{r_2^{\beta_2}}{\Omega_2}} \left[1 - Q_1\left(\frac{\sqrt{2\rho_2}}{\sqrt{\Omega_2(1-\rho_2)}} r_2^{\beta_2/2}, \frac{\sqrt{2}}{\sqrt{\Omega_2(1-\rho_2)}} r_T^{\beta_2/2}\right)\right] \tag{3.6.15}$$

Za $r_1 \geq r_T$, $r_2<r_T$

$$p_{r_1r_2}(r_1,r_2) = P_1 \frac{\beta_1}{\Omega_1} r_1^{\beta_1-1} e^{-\frac{r_1^{\beta_1}}{\Omega_1}} \frac{\beta_2}{\Omega_2} r_2^{\beta_2-1} e^{-\frac{r_2^{\beta_2}}{\Omega_2}} \left[1 - Q_1\left(\frac{\sqrt{2\rho_1}}{\sqrt{\Omega_1(1-\rho_1)}} r_1^{\beta_1/2}, \frac{\sqrt{2}}{\sqrt{\Omega_1(1-\rho_1)}} r_T^{\beta_1/2}\right)\right] +$$

$$+P_1\frac{\beta_2}{\Omega_2}r_1^{\beta_2-1}e^{-\frac{r_1^{\beta_2}}{\Omega_2}}\left[1-Q_1\left(\frac{\sqrt{2\rho_2}}{\sqrt{\Omega_2(1-\rho_2)}}r_1^{\beta_2/2},\frac{\sqrt{2}}{\sqrt{\Omega_2(1-\rho_2)}}r_T^{\beta_2/2}\right)\right]\cdot$$

$$\cdot\frac{\beta_1}{\Omega_1}r_2^{\beta_1-1}e^{-\frac{r_2^{\beta_1}}{\Omega_1}}\left[1-Q_1\left(\frac{\sqrt{2\rho_1}}{\sqrt{\Omega_1(1-\rho_1)}}r_2^{\beta_1/2},\frac{\sqrt{2}}{\sqrt{\Omega_1(1-\rho_1)}}r_T^{\beta_1/2}\right)\right]+$$

$$+P_2\frac{\beta_2}{\Omega_2}r_1^{\beta_2-1}e^{-\frac{r_1^{\beta_2}}{\Omega_2}}\frac{\beta_1}{\Omega_1}r_2^{\beta_1-1}e^{-\frac{r_2^{\beta_1}}{\Omega_1}}\left[1-Q_1\left(\frac{\sqrt{2\rho_2}}{\sqrt{\Omega_2(1-\rho_2)}}r_1^{\beta_2/2},\frac{\sqrt{2}}{\sqrt{\Omega_2(1-\rho_2)}}r_T^{\beta_2/2}\right)\right]+$$

$$+P_2\frac{\beta_1}{\Omega_1}r_1^{\beta_1-1}e^{-\frac{r_1^{\beta_1}}{\Omega_1}}\left[1-Q_1\left(\frac{\sqrt{2\rho_1}}{\sqrt{\Omega_1(1-\rho_1)}}r_1^{\beta_1/2},\frac{\sqrt{2}}{\sqrt{\Omega_1(1-\rho_1)}}r_T^{\beta_1/2}\right)\right]\cdot$$

$$\cdot\frac{\beta_2}{\Omega_2}r_2^{\beta_2-1}e^{-\frac{r_2^{\beta_2}}{\Omega_2}}\left[1-Q_1\left(\frac{\sqrt{2\rho_2}}{\sqrt{\Omega_2(1-\rho_2)}}r_2^{\beta_2/2},\frac{\sqrt{2}}{\sqrt{\Omega_2(1-\rho_2)}}r_T^{\beta_2/2}\right)\right] \qquad (3.6.16)$$

Za $r_1<r_T$, $r_2\geq r_T$

$$p_{r_1r_2}(r_1,r_2)=P_1\left(1-e^{-\frac{r_T^{\beta_1}}{\Omega_1}}\right)\frac{\beta_2^{\,2}(r_1r_2)^{\beta_1-1}}{\Omega_2^{\,2}(1-\rho_2)}e^{-\frac{1}{1-\rho_2}\left(\frac{r_1^{\beta_2}}{\Omega_2}+\frac{r_2^{\beta_2}}{\Omega_2}\right)}I_0\left[\frac{2\sqrt{\rho_2}r_1^{\beta_2/2}r_2^{\beta_2/2}}{(1-\rho_2)\Omega_2}\right]+$$

$$+P_1\frac{\beta_2}{\Omega_2}r_1^{\beta_2-1}e^{-\frac{r_1^{\beta_2}}{\Omega_2}}\left[1-Q_1\left(\frac{\sqrt{2\rho_2}}{\sqrt{\Omega_2(1-\rho_2)}}r_1^{\beta_2/2},\frac{\sqrt{2}}{\sqrt{\Omega_2(1-\rho_2)}}r_T^{\beta_2/2}\right)\right]\cdot$$

$$\cdot\frac{\beta_1}{\Omega_1}r_2^{\beta_1-1}e^{-\frac{r_2^{\beta_1}}{\Omega_1}}\left[1-Q_1\left(\frac{\sqrt{2\rho_1}}{\sqrt{\Omega_1(1-\rho_1)}}r_2^{\beta_1/2},\frac{\sqrt{2}}{\sqrt{\Omega_1(1-\rho_1)}}r_T^{\beta_1/2}\right)\right]+$$

$$+P_2\left(1-e^{-\frac{r_T^{\beta_2}}{\Omega_2}}\right)\frac{\beta_1^{\,2}(r_1r_2)^{\beta_1-1}}{\Omega_1^{\,2}(1-\rho_1)}e^{-\frac{1}{1-\rho_1}\left(\frac{r_1^{\beta_1}}{\Omega_1}+\frac{r_2^{\beta_1}}{\Omega_1}\right)}I_0\left[\frac{2\sqrt{\rho_1}r_1^{\beta_1/2}r_2^{\beta_1/2}}{(1-\rho_1)\Omega_1}\right]+$$

$$+P_2\frac{\beta_1}{\Omega_1}r_1^{\beta_1-1}e^{-\frac{r_1^{\beta_1}}{\Omega_1}}\left[1-Q_1\left(\frac{\sqrt{2\rho_1}}{\sqrt{\Omega_1(1-\rho_1)}}r_1^{\beta_1/2},\frac{\sqrt{2}}{\sqrt{\Omega_1(1-\rho_1)}}r_T^{\beta_1/2}\right)\right]\cdot$$

$$\cdot\frac{\beta_2}{\Omega_2}r_2^{\beta_2-1}e^{-\frac{r_2^{\beta_2}}{\Omega_2}}\left[1-Q_1\left(\frac{\sqrt{2\rho_2}}{\sqrt{\Omega_2(1-\rho_2)}}r_2^{\beta_2/2},\frac{\sqrt{2}}{\sqrt{\Omega_2(1-\rho_2)}}r_T^{\beta_2/2}\right)\right] \qquad (3.6.17)$$

Za $r_1\geq r_T$, $r_2\geq r_T$

$$p_{r_1r_2}(r_1,r_2)=P_1\frac{\beta_1^{\,2}(r_1r_2)^{\beta_1-1}}{\Omega_1^{\,2}(1-\rho_1)}e^{-\frac{1}{1-\rho_1}\left(\frac{r_1^{\beta_1}}{\Omega_1}+\frac{r_2^{\beta_1}}{\Omega_1}\right)}I_0\left[\frac{2\sqrt{\rho_1}r_1^{\beta_1/2}r_2^{\beta_1/2}}{(1-\rho_1)\Omega_1}\right]+$$

$$+P_1\frac{\beta_1}{\Omega_1}r_1^{\beta_1-1}e^{-\frac{r_1^{\beta_1}}{\Omega_1}}\frac{\beta_2}{\Omega_2}r_2^{\beta_2-1}e^{-\frac{r_2^{\beta_2}}{\Omega_2}}\left[1-Q_1\left(\frac{\sqrt{2\rho_1}}{\sqrt{\Omega_1(1-\rho_1)}}r_1^{\beta_1/2},\frac{\sqrt{2}}{\sqrt{\Omega_1(1-\rho_1)}}r_T^{\beta_1/2}\right)\right]+$$

$$+P_1\left(1-e^{-\frac{r_T^{\beta_1}}{\Omega_1}}\right)\frac{\beta_2^{\,2}\left(r_1r_2\right)^{\beta_1-1}}{\Omega_2^{\,2}\left(1-\rho_2\right)}e^{-\frac{1}{1-\rho_2}\left(\frac{r_1^{\beta_2}}{\Omega_2}+\frac{r_2^{\beta_2}}{\Omega_2}\right)}I_0\left[\frac{2\sqrt{\rho_2}\,r_1^{\beta_2/2}r_2^{\beta_2/2}}{\left(1-\rho_2\right)\Omega_2}\right]+$$

$$+P_1\frac{\beta_2}{\Omega_2}r_1^{\beta_2-1}e^{-\frac{r_1^{\beta_2}}{\Omega_2}}\left[1-Q_1\left(\frac{\sqrt{2\rho_2}}{\sqrt{\Omega_2(1-\rho_2)}}r_1^{\beta_2/2},\frac{\sqrt{2}}{\sqrt{\Omega_2(1-\rho_2)}}r_T^{\beta_2/2}\right)\right]\cdot$$

$$\cdot\frac{\beta_1}{\Omega_1}r_2^{\beta_1-1}e^{-\frac{r_2^{\beta_1}}{\Omega_1}}\left[1-Q_1\left(\frac{\sqrt{2\rho_1}}{\sqrt{\Omega_1(1-\rho_1)}}r_2^{\beta_1/2},\frac{\sqrt{2}}{\sqrt{\Omega_1(1-\rho_1)}}r_T^{\beta_1/2}\right)\right]+$$

$$+P_2\frac{\beta_1^{\,2}\left(r_1r_2\right)^{\beta_1-1}}{\Omega_1^{\,2}\left(1-\rho_1\right)}e^{-\frac{1}{1-\rho_1}\left(\frac{r_1^{\beta_1}}{\Omega_1}+\frac{r_2^{\beta_1}}{\Omega_1}\right)}I_0\left[\frac{2\sqrt{\rho_1}\,r_1^{\beta_1/2}r_2^{\beta_1/2}}{\left(1-\rho_1\right)\Omega_1}\right]+$$

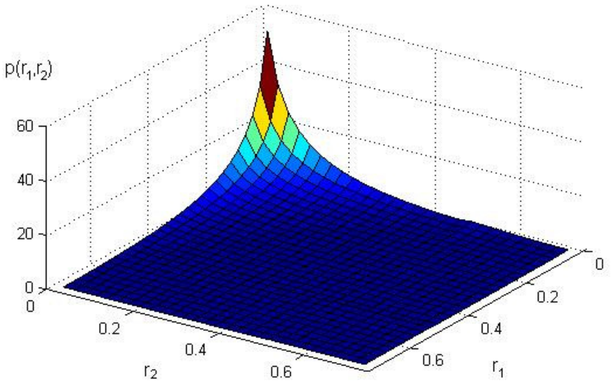
$$+P_2\frac{\beta_2}{\Omega_2}r_1^{\beta_2-1}e^{-\frac{r_1^{\beta_2}}{\Omega_2}}\frac{\beta_1}{\Omega_1}r_2^{\beta_1-1}e^{-\frac{r_2^{\beta_1}}{\Omega_1}}\left[1-Q_1\left(\frac{\sqrt{2\rho_2}}{\sqrt{\Omega_2(1-\rho_2)}}r_1^{\beta_2/2},\frac{\sqrt{2}}{\sqrt{\Omega_2(1-\rho_2)}}r_t^{\beta_2/2}\right)\right]+$$

$$+P_2\left(1-e^{-\frac{r_T^{\beta_2}}{\Omega_2}}\right)\frac{\beta_1^{\,2}\left(r_1r_2\right)^{\beta_1-1}}{\Omega_1^{\,2}\left(1-\rho_1\right)}e^{-\frac{1}{1-\rho_1}\left(\frac{r_1^{\beta_1}}{\Omega_1}+\frac{r_2^{\beta_1}}{\Omega_1}\right)}I_0\left[\frac{2\sqrt{\rho_1}\,r_1^{\beta_1/2}r_2^{\beta_1/2}}{\left(1-\rho_1\right)\Omega_1}\right]+$$

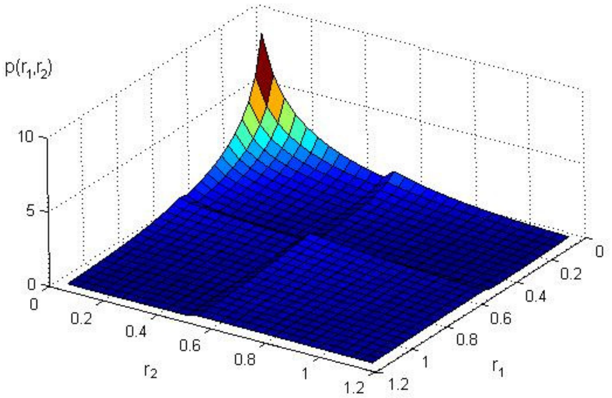
$$+P_2\frac{\beta_1}{\Omega_1}r_1^{\beta_1-1}e^{-\frac{r_1^{\beta_1}}{\Omega_1}}\left[1-Q_1\left(\frac{\sqrt{2\rho_1}}{\sqrt{\Omega_1(1-\rho_1)}}r_1^{\beta_1/2},\frac{\sqrt{2}}{\sqrt{\Omega_1(1-\rho_1)}}r_T^{\beta_1/2}\right)\right]\cdot$$

$$\cdot\frac{\beta_2}{\Omega_2}r_2^{\beta_2-1}e^{-\frac{r_2^{\beta_2}}{\Omega_2}}\left[1-Q_1\left(\frac{\sqrt{2\rho_2}}{\sqrt{\Omega_2(1-\rho_2)}}r_2^{\beta_2/2},\frac{\sqrt{2}}{\sqrt{\Omega_2(1-\rho_2)}}r_T^{\beta_2/2}\right)\right]\tag{3.6.18}$$

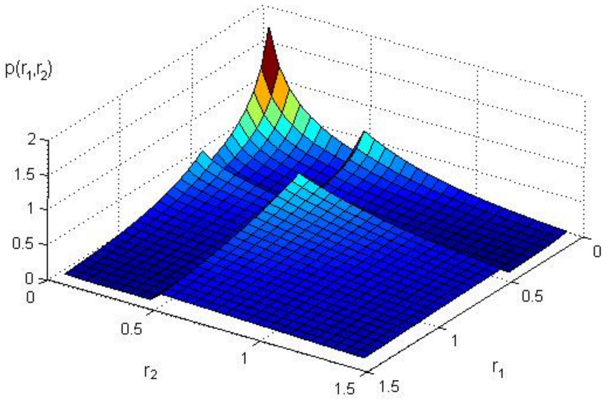
Na slikama 3.6.1.-9. predstavljena je zavisnost PDF od vrednosti signala za različite vrednosti parametara raspodele, korelacije i praga odlučivanja. Radi uproštavanje, a ne gubeći uopštenost, pretpostavljeno je da su parametri raspodele isti za obe grane kombinera.



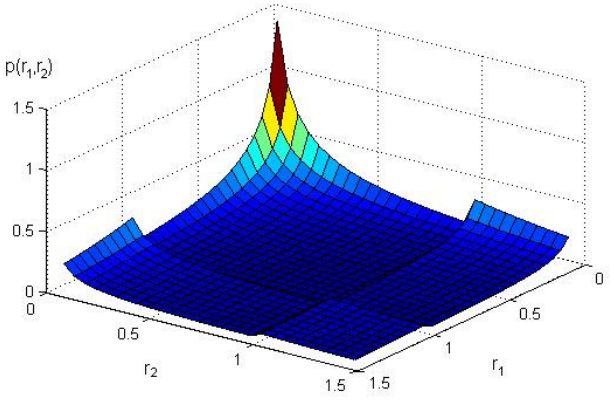
Slika 3.6.1. Združena gustina raspodele verovatnoće na izlazu iz SSC kombinera u dva trenutka vremena u prisustvu Weibull-ovog fedinga za parametre: $\rho = 0.8$, $r_T = 0.5$, $\beta = 0.7$, $\Omega = 0.2$



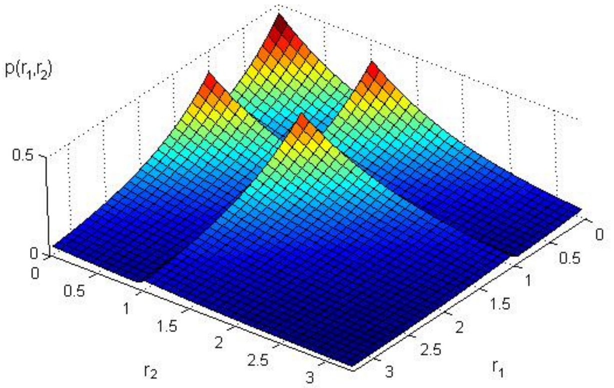
Slika 3.6.2. Združena gustina raspodele verovatnoće na izlazu iz SSC kombinera u dva trenutka vremena u prisustvu Weibull-ovog fedinga za parametre: $\rho = 0.8$, $r_T = 0.5$, $\beta = 0.7$, $\Omega = 0.5$



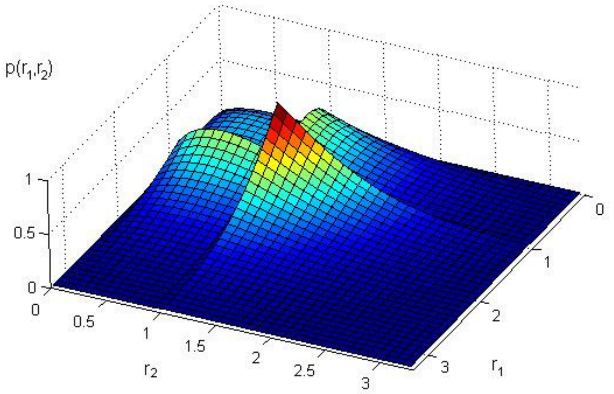
Slika 3.6.3. Združena gustina raspodele verovatnoće na izlazu iz SSC kombinera u dva trenutka vremena u prisustvu Weibull-ovog fedinga za parametre: $\rho = 0.8$, $r_T = 0.5$, $\beta = 0.7$, $\Omega = 1$



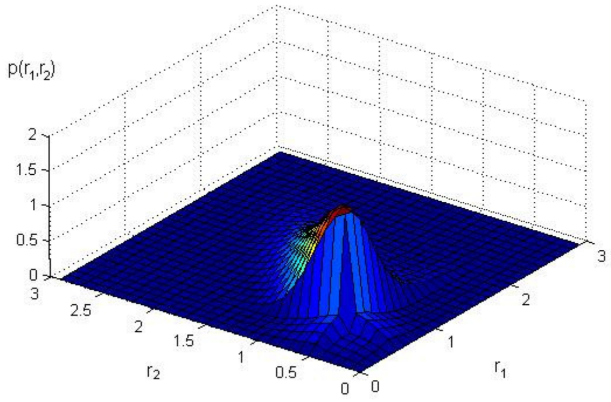
Slika 3.6.4. Združena gustina raspodele verovatnoće na izlazu iz SSC kombinera u dva trenutka vremena u prisustvu Weibull-ovog fedinga za parametre: $\rho = 0.1$, $r_T = 1$, $\Omega = 1$, $\beta = 0.5$



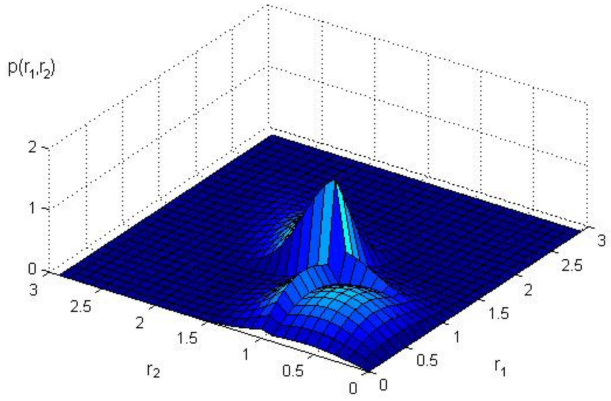
Slika 3.6.5. Združena gustina raspodele verovatnoće na izlazu iz SSC kombinera u dva trenutka vremena u prisustvu Weibull-ovog fedinga za parametre: $\rho = 0.1$, $r_T = 1$, $\Omega = 1$, $\beta = 1$



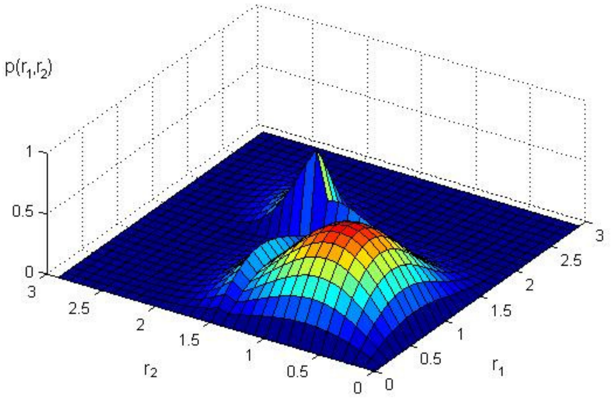
Slika 3.6.6. Združena gustina raspodele verovatnoće na izlazu iz SSC kombinera u dva trenutka vremena u prisustvu Weibull-ovog fedinga za parametre: $\rho = 0.1$, $r_T = 1$, $\Omega = 1$, $\beta = 1.5$



Slika 3.6.7. Združena gustina raspodele verovatnoće na izlazu iz SSC kombinera u dva trenutka vremena u prisustvu Weibull-ovog fedinga za parametre: $\rho = 0.8$, $\beta = 2$, $\Omega = 1$, $r_T = 0.5$



Slika 3.6.8. Združena gustina raspodele verovatnoće na izlazu iz SSC kombinera u dva trenutka vremena u prisustvu Weibull-ovog fedinga za parametre: $\rho = 0.8$, $\beta = 2$, $\Omega = 1$, $r_T = 1$



Slika 3.6.9. Združena gustina raspodele verovatnoće na izlazu iz SSC kombinera u dva trenutka vremena u prisustvu Weibull-ovog fedinga za parametre: $\rho = 0.8$, $\beta = 2$, $\Omega = 1$, $r_T = 1.5$

3.7 Združena gustina raspodele verovatnoće na izlazu SSC kombinera u dva trenutka vremena u prisustvu log-normalnog fedinga

Gustina raspodele verovatnoće i kumulativna raspodela verovatnoće (CDF) signala na izlazu iz kombinera $r_{i,j}$ u prisustvu log-normalnog fedinga su [9], [10]:

$$p_{r_i}(r_{i,j}) = \frac{1}{\sqrt{2\pi}\sigma_i r_{i,j}} e^{-\frac{(\ln r_{i,j}-\mu_i)^2}{2\sigma_i^2}}, \qquad r_{i,j} \geq 0 \tag{3.7.1}$$

$$F_{r_i}(r_{i,j}) = \frac{1}{2} + \frac{1}{2} erf\left(\frac{\ln r_{i,j}-\mu_i}{\sigma_i\sqrt{2}}\right) \qquad , \quad r_{i,j} \geq 0 \tag{3.7.2}$$

gde su *i=1,2 j=1,2*, μ je srednja vrednost signal, σ je standardna devijacija, a *erf(x)* je funkcija greške definisana sa [55]:

$$erf(x) = \frac{2}{\sqrt{\pi}} \int_0^x e^{-t^2} dt \tag{3.7.3}$$

CDF se može dobiti i pomoću jednodimenzione Gauss-ove *Q* funkcije:

$$F_{r_i}(r_{i,j}) = 1 - Q\left(\frac{\ln r_{i,j}-\mu_i}{\sigma_i}\right) \qquad , \quad r_{i,j} \geq 0 \tag{3.7.4}$$

gde je [1]:

$$Q(x) = \frac{1}{\sqrt{2\pi}} \int_x^\infty e^{-t^2/2} dt \tag{3.7.5}$$

Verovatnoće P_1 i P_2 se dobijaju ako se u (3.1.17-18) stavi (3.7.4):

$$P_1 = \frac{F_{r_2}(r_T)}{F_{r_1}(r_T) + F_{r_2}(r_T)} = \frac{1 - Q\left(\frac{\ln r_T - \mu_2}{\sigma_2}\right)}{2 - \left(Q\left(\frac{\ln r_T - \mu_1}{\sigma_1}\right) - Q\left(\frac{\ln r_T - \mu_2}{\sigma_2}\right)\right)} \tag{3.7.6}$$

$$P_2 = \frac{F_{r_1}(r_T)}{F_{r_1}(r_T) + F_{r_2}(r_T)} = \frac{1 - Q\left(\frac{\ln r_T - \mu_1}{\sigma_1}\right)}{2 - \left(Q\left(\frac{\ln r_T - \mu_1}{\sigma_1}\right) - Q\left(\frac{\ln r_T - \mu_2}{\sigma_2}\right)\right)} \tag{3.7.7}$$

Združena gustina raspodele verovatnoće korelisanih signala *x₁* i *x₂* sa log-normalnom raspodelom i istim parametrima raspodele σ je [10]:

$$p_{x_1x_2}(x_1,x_2)=\frac{1}{2\pi\sigma^2\sqrt{1-\rho^2}\,x_1x_2}e^{-\frac{1}{2(1-\rho^2)}\left[\left(\frac{\ln x_1-\mu}{\sigma}\right)^2+\left(\frac{\ln x_2-\mu}{\sigma}\right)^2-2\rho\left(\frac{\ln x_1-\mu}{\sigma}\right)\left(\frac{\ln x_2-\mu}{\sigma}\right)\right]} \tag{3.7.8}$$

gde je ρ koeficijent korelacije.

Združena gustina raspodele verovatnoće signala r_1 i r_2 na izlazu SSC kombinera u dva trenutka vremena u prisustvu log-normalnog fedinga kada su signali na ulazu u grane kombinera nezavisni, može se dobiti ako se u (3.2.5-8) stave izrazi (3.7.1) i (3.7.8).

Za $r_1<r_T$, $r_2<r_T$

$$p_{r_1r_2}(r_1,r_2)=P_1\int_0^{r_T}\frac{1}{2\pi\sigma_1{}^2\sqrt{1-\rho_1{}^2}\,r_{11}r_2}e^{-\frac{1}{2(1-\rho_1{}^2)}\left[\left(\frac{\ln r_{11}-\mu_1}{\sigma_1}\right)^2+\left(\frac{\ln r_2-\mu_1}{\sigma_1}\right)^2-2\rho_1\left(\frac{\ln r_{11}-\mu_1}{\sigma_1}\right)\left(\frac{\ln r_2-\mu_1}{\sigma_1}\right)\right]}dr_{11}\cdot$$

$$\cdot\int_0^{r_T}\frac{1}{2\pi\sigma_2{}^2\sqrt{1-\rho_2{}^2}\,r_{22}r_1}e^{-\frac{1}{2(1-\rho_2{}^2)}\left[\left(\frac{\ln r_{22}-\mu_2}{\sigma_2}\right)^2+\left(\frac{\ln r_1-\mu_2}{\sigma_2}\right)^2-2\rho_2\left(\frac{\ln r_{22}-\mu_2}{\sigma_2}\right)\left(\frac{\ln r_1-\mu_2}{\sigma_2}\right)\right]}dr_{22}+$$

$$+P_2\int_0^{r_T}\frac{1}{2\pi\sigma_2{}^2\sqrt{1-\rho_2{}^2}\,r_{21}r_2}e^{-\frac{1}{2(1-\rho_2{}^2)}\left[\left(\frac{\ln r_{21}-\mu_2}{\sigma_2}\right)^2+\left(\frac{\ln r_2-\mu_2}{\sigma_2}\right)^2-2\rho_2\left(\frac{\ln r_{21}-\mu_2}{\sigma_2}\right)\left(\frac{\ln r_2-\mu_2}{\sigma_2}\right)\right]}dr_{21}\cdot$$

$$\cdot\int_0^{r_T}\frac{1}{2\pi\sigma_1{}^2\sqrt{1-\rho_1{}^2}\,r_{12}r_1}e^{-\frac{1}{2(1-\rho_1{}^2)}\left[\left(\frac{\ln r_{12}-\mu_1}{\sigma_1}\right)^2+\left(\frac{\ln r_1-\mu_1}{\sigma_1}\right)^2-2\rho_1\left(\frac{\ln r_{12}-\mu_1}{\sigma_1}\right)\left(\frac{\ln r_1-\mu_1}{\sigma_1}\right)\right]}dr_{12} \tag{3.7.9}$$

Za $r_1\geq r_T$, $r_2<r_T$

$$p_{r_1r_2}(r_1,r_2)=$$

$$=P_1\frac{1}{\sqrt{2\pi}\sigma_2r_2}e^{-\frac{(\ln r_2-\mu_2)^2}{2\sigma_2{}^2}}\int_0^{r_T}\frac{1}{2\pi\sigma_1{}^2\sqrt{1-\rho_1{}^2}\,r_{12}r_1}e^{-\frac{1}{2(1-\rho_1{}^2)}\left[\left(\frac{\ln r_{12}-\mu_1}{\sigma_1}\right)^2+\left(\frac{\ln r_1-\mu_1}{\sigma_1}\right)^2-2\rho\left(\frac{\ln r_{12}-\mu_1}{\sigma_1}\right)\left(\frac{\ln r_1-\mu_1}{\sigma_1}\right)\right]}dr_{12}+$$

$$+P_1\int_0^{r_T}\frac{1}{2\pi\sigma_1{}^2\sqrt{1-\rho_1{}^2}\,r_{11}r_2}e^{-\frac{1}{2(1-\rho_1{}^2)}\left[\left(\frac{\ln r_{11}-\mu_1}{\sigma_1}\right)^2+\left(\frac{\ln r_2-\mu_1}{\sigma_1}\right)^2-2\rho_1\left(\frac{\ln r_{11}-\mu_1}{\sigma_1}\right)\left(\frac{\ln r_2-\mu_1}{\sigma_1}\right)\right]}dr_{11}\cdot$$

$$\cdot\int_0^{r_T}\frac{1}{2\pi\sigma_2{}^2\sqrt{1-\rho_2{}^2}\,r_{22}r_1}e^{-\frac{1}{2(1-\rho_2{}^2)}\left[\left(\frac{\ln r_{22}-\mu_2}{\sigma_2}\right)^2+\left(\frac{\ln r_1-\mu_2}{\sigma_2}\right)^2-2\rho_2\left(\frac{\ln r_{22}-\mu_2}{\sigma_2}\right)\left(\frac{\ln r_1-\mu_2}{\sigma_2}\right)\right]}dr_{22}+$$

$$+P_2\frac{1}{\sqrt{2\pi}\sigma_1 r_2}e^{-\frac{(\ln r_2-\mu_1)^2}{2\sigma_1^{\,2}}}\int_0^{r_T}\frac{1}{2\pi\sigma_2^{\,2}\sqrt{1-\rho_2^{\,2}}\,r_{22}r_1}e^{-\frac{1}{2\left(1-\rho_2^{\,2}\right)}\left[\left(\frac{\ln r_{22}-\mu_2}{\sigma_2}\right)^2+\left(\frac{\ln r_1-\mu_2}{\sigma_2}\right)^2-2\rho_2\left(\frac{\ln r_{22}-\mu_2}{\sigma_2}\right)\left(\frac{\ln r_1-\mu_2}{\sigma_2}\right)\right]}dr_{22}+$$

$$+P_2\int_0^{r_T}\frac{1}{2\pi\sigma_2^{\,2}\sqrt{1-\rho_2^{\,2}}\,r_{21}r_2}e^{-\frac{1}{2\left(1-\rho_2^{\,2}\right)}\left[\left(\frac{\ln r_{21}-\mu_2}{\sigma_2}\right)^2+\left(\frac{\ln r_2-\mu_2}{\sigma_2}\right)^2-2\rho_2\left(\frac{\ln r_{21}-\mu_2}{\sigma_2}\right)\left(\frac{\ln r_2-\mu_2}{\sigma_2}\right)\right]}dr_{21}\cdot$$

$$\cdot\int_0^{r_T}\frac{1}{2\pi\sigma_1^{\,2}\sqrt{1-\rho_1^{\,2}}\,r_{12}r_1}e^{-\frac{1}{2\left(1-\rho_1^{\,2}\right)}\left[\left(\frac{\ln r_{12}-\mu_1}{\sigma_1}\right)^2+\left(\frac{\ln r_1-\mu_1}{\sigma_1}\right)^2-2\rho_1\left(\frac{\ln r_{12}-\mu_1}{\sigma_1}\right)\left(\frac{\ln r_1-\mu_1}{\sigma_1}\right)\right]}dr_{12}\qquad(3.7.10)$$

Za $r_1<r_T$, $r_2\geq r_T$

$$p_{r_1r_2}(r_1,r_2)=$$

$$=P_1\left(1-Q\left(\frac{\ln r_T-\mu_1}{\sigma_1}\right)\right)\frac{1}{2\pi\sigma_2^{\,2}\sqrt{1-\rho_2^{\,2}}\,r_1r_2}e^{-\frac{1}{2\left(1-\rho_2^{\,2}\right)}\left[\left(\frac{\ln r_1-\mu_2}{\sigma_2}\right)^2+\left(\frac{\ln r_2-\mu_2}{\sigma_2}\right)^2-2\rho_2\left(\frac{\ln r_1-\mu_2}{\sigma_2}\right)\left(\frac{\ln r_2-\mu_2}{\sigma_2}\right)\right]}+$$

$$+P_1\int_0^{r_T}\frac{1}{2\pi\sigma_1^{\,2}\sqrt{1-\rho_1^{\,2}}\,r_{11}r_2}e^{-\frac{1}{2\left(1-\rho_1^{\,2}\right)}\left[\left(\frac{\ln r_{11}-\mu_1}{\sigma_1}\right)^2+\left(\frac{\ln r_2-\mu_1}{\sigma_1}\right)^2-2\rho_1\left(\frac{\ln r_{11}-\mu_1}{\sigma_1}\right)\left(\frac{\ln r_2-\mu_1}{\sigma_1}\right)\right]}dr_{11}\cdot$$

$$\cdot\int_0^{r_T}\frac{1}{2\pi\sigma_2^{\,2}\sqrt{1-\rho_2^{\,2}}\,r_{22}r_1}e^{-\frac{1}{2\left(1-\rho_2^{\,2}\right)}\left[\left(\frac{\ln r_{22}-\mu_2}{\sigma_2}\right)^2+\left(\frac{\ln r_1-\mu_2}{\sigma_2}\right)^2-2\rho_2\left(\frac{\ln r_{22}-\mu_2}{\sigma_2}\right)\left(\frac{\ln r_1-\mu_2}{\sigma_2}\right)\right]}dr_{22}+$$

$$+P_2\left(1-Q\left(\frac{\ln r_T-\mu_2}{\sigma_2}\right)\right)\frac{1}{2\pi\sigma_1^{\,2}\sqrt{1-\rho_1^{\,2}}\,r_1r_2}e^{-\frac{1}{2\left(1-\rho_1^{\,2}\right)}\left[\left(\frac{\ln r_1-\mu_1}{\sigma_1}\right)^2+\left(\frac{\ln r_2-\mu_1}{\sigma_1}\right)^2-2\rho_1\left(\frac{\ln r_1-\mu_1}{\sigma_1}\right)\left(\frac{\ln r_2-\mu_1}{\sigma_1}\right)\right]}+$$

$$+P_2\int_0^{r_T}\frac{1}{2\pi\sigma_2^{\,2}\sqrt{1-\rho_2^{\,2}}\,r_{21}r_2}e^{-\frac{1}{2\left(1-\rho_2^{\,2}\right)}\left[\left(\frac{\ln r_{21}-\mu_2}{\sigma_2}\right)^2+\left(\frac{\ln r_2-\mu_2}{\sigma_2}\right)^2-2\rho_2\left(\frac{\ln r_{21}-\mu_2}{\sigma_2}\right)\left(\frac{\ln r_2-\mu_2}{\sigma_2}\right)\right]}dr_{21}\cdot$$

$$\cdot\int_0^{r_T}\frac{1}{2\pi\sigma_1^{\,2}\sqrt{1-\rho_1^{\,2}}\,r_{12}r_1}e^{-\frac{1}{2\left(1-\rho_1^{\,2}\right)}\left[\left(\frac{\ln r_{12}-\mu_1}{\sigma_1}\right)^2+\left(\frac{\ln r_1-\mu_1}{\sigma_1}\right)^2-2\rho_1\left(\frac{\ln r_{12}-\mu_1}{\sigma_1}\right)\left(\frac{\ln r_1-\mu_1}{\sigma_1}\right)\right]}dr_{12}\qquad(3.7.11)$$

Za $r_1\geq r_T$, $r_2\geq r_T$

$$p_{r_1r_2}(r_1,r_2)=P_1\frac{1}{2\pi\sigma_1^{\,2}\sqrt{1-\rho_1^{\,2}}\,r_1r_2}e^{-\frac{1}{2\left(1-\rho_1^{\,2}\right)}\left[\left(\frac{\ln r_1-\mu_1}{\sigma_1}\right)^2+\left(\frac{\ln r_2-\mu_1}{\sigma_1}\right)^2-2\rho_1\left(\frac{\ln r_1-\mu_1}{\sigma_1}\right)\left(\frac{\ln r_2-\mu_1}{\sigma_1}\right)\right]}+$$

$$+P_1\frac{1}{\sqrt{2\pi}\sigma_2 r_2}e^{-\frac{(\ln r_2-\mu_2)^2}{2\sigma_2^{\,2}}}\int_0^{r_T}\frac{1}{2\pi\sigma_1^{\,2}\sqrt{1-\rho_1^{\,2}}\,r_{12}r_1}e^{-\frac{1}{2\left(1-\rho_1^{\,2}\right)}\left[\left(\frac{\ln r_{12}-\mu_1}{\sigma_1}\right)^2+\left(\frac{\ln r_1-\mu_1}{\sigma_1}\right)^2-2\rho_1\left(\frac{\ln r_{12}-\mu_1}{\sigma_1}\right)\left(\frac{\ln r_1-\mu_1}{\sigma_1}\right)\right]}dr_{12}+$$

$$+P_1\left(1-Q\left(\frac{\ln r_T-\mu_1}{\sigma_1}\right)\right)\frac{1}{2\pi\sigma_2{}^2\sqrt{1-\rho_2{}^2}\,r_1r_2}e^{-\frac{1}{2\left(1-\rho_2{}^2\right)}\left[\left(\frac{\ln r_1-\mu_2}{\sigma_2}\right)^2+\left(\frac{\ln r_2-\mu_2}{\sigma_2}\right)^2-2\rho_2\left(\frac{\ln r_1-\mu_2}{\sigma_2}\right)\left(\frac{\ln r_2-\mu_2}{\sigma_2}\right)\right]}+$$

$$+P_1\int_0^{r_T}\frac{1}{2\pi\sigma_1{}^2\sqrt{1-\rho_1{}^2}\,r_{11}r_2}e^{-\frac{1}{2\left(1-\rho_1{}^2\right)}\left[\left(\frac{\ln r_{11}-\mu_1}{\sigma_1}\right)^2+\left(\frac{\ln r_2-\mu_1}{\sigma_1}\right)^2-2\rho_1\left(\frac{\ln r_{11}-\mu_1}{\sigma_1}\right)\left(\frac{\ln r_2-\mu_1}{\sigma_1}\right)\right]}dr_{11}\cdot$$

$$\cdot\int_0^{r_T}\frac{1}{2\pi\sigma_2{}^2\sqrt{1-\rho_2{}^2}\,r_{22}r_1}e^{-\frac{1}{2\left(1-\rho_2{}^2\right)}\left[\left(\frac{\ln r_{22}-\mu_2}{\sigma_2}\right)^2+\left(\frac{\ln r_1-\mu_2}{\sigma_2}\right)^2-2\rho_2\left(\frac{\ln r_{22}-\mu_2}{\sigma_2}\right)\left(\frac{\ln r_1-\mu_2}{\sigma_2}\right)\right]}dr_{22}+$$

$$+P_2\frac{1}{2\pi\sigma_2{}^2\sqrt{1-\rho_2{}^2}\,r_1r_2}e^{-\frac{1}{2\left(1-\rho_2{}^2\right)}\left[\left(\frac{\ln r_1-\mu_2}{\sigma_2}\right)^2+\left(\frac{\ln r_2-\mu_2}{\sigma_2}\right)^2-2\rho_2\left(\frac{\ln r_1-\mu_2}{\sigma_2}\right)\left(\frac{\ln r_2-\mu_2}{\sigma_2}\right)\right]}+$$

$$+P_2\frac{1}{\sqrt{2\pi}\sigma_1r_2}e^{-\frac{(\ln r_2-\mu_1)^2}{2\sigma_1{}^2}}\int_0^{r_T}\frac{1}{2\pi\sigma_2{}^2\sqrt{1-\rho_2{}^2}\,r_{22}r_1}e^{-\frac{1}{2\left(1-\rho_2{}^2\right)}\left[\left(\frac{\ln r_{22}-\mu_2}{\sigma_2}\right)^2+\left(\frac{\ln r_1-\mu_2}{\sigma_2}\right)^2-2\rho_2\left(\frac{\ln r_{22}-\mu_2}{\sigma_2}\right)\left(\frac{\ln r_1-\mu_2}{\sigma_2}\right)\right]}dr_{22}+$$

$$+P_2\left(1-Q\left(\frac{\ln r_T-\mu_2}{\sigma_2}\right)\right)\frac{1}{2\pi\sigma_1{}^2\sqrt{1-\rho_1{}^2}\,r_1r_2}e^{-\frac{1}{2\left(1-\rho_1{}^2\right)}\left[\left(\frac{\ln r_1-\mu_1}{\sigma_1}\right)^2+\left(\frac{\ln r_1-\mu_1}{\sigma_1}\right)^2-2\rho_1\left(\frac{\ln r_1-\mu_1}{\sigma_1}\right)\left(\frac{\ln r_2-\mu_1}{\sigma_1}\right)\right]}+$$

$$+P_2\int_0^{r_T}\frac{1}{2\pi\sigma_2{}^2\sqrt{1-\rho_2{}^2}\,r_{21}r_2}e^{-\frac{1}{2\left(1-\rho_2{}^2\right)}\left[\left(\frac{\ln r_{21}-\mu_2}{\sigma_2}\right)^2+\left(\frac{\ln r_2-\mu_2}{\sigma_2}\right)^2-2\rho_2\left(\frac{\ln r_{21}-\mu_2}{\sigma_2}\right)\left(\frac{\ln r_2-\mu_2}{\sigma_2}\right)\right]}dr_{21}\cdot$$

$$\cdot\int_0^{r_T}\frac{1}{2\pi\sigma_1{}^2\sqrt{1-\rho_1{}^2}\,r_{12}r_1}e^{-\frac{1}{2\left(1-\rho_1{}^2\right)}\left[\left(\frac{\ln r_{12}-\mu_1}{\sigma_1}\right)^2+\left(\frac{\ln r_1-\mu_1}{\sigma_1}\right)^2-2\rho_1\left(\frac{\ln r_{12}-\mu_1}{\sigma_1}\right)\left(\frac{\ln r_1-\mu_1}{\sigma_1}\right)\right]}dr_{12} \qquad (3.7.12)$$

Izrazi (3.3.81-84) su u obliku jednostrukog integrala sa konačnim granicama. Združena gustina raspodele verovatnoće se može dobiti u zatvorenom obliku korišćenjem jednodimenzione Gauss-ove Q funkcije.

Za predstavljanje združene PDF u zatvorenom obliku potrebno je rešiti integral $\int_{r_T}^{\infty} p_{x_1x_2}(x_1,x_2)dx_1$, gde je $p_{x_1x_2}(x_1,x_2)$ dato u (3.3.80). Transformacijom $p_{x_1x_2}(x_1,x_2)$, ona se može predstaviti u obliku koji u podintegralnom delu predstavlja podintegralni deo jednodimenzione Gauss-ove Q funkcije.

$$x_1=e^{x\sqrt{\left(1-\rho^2\right)}\sigma}x_2e^{\mu(1-\rho)} \qquad x=\frac{\ln x_1-\mu(1-\rho)-\rho\ln x_2}{\sqrt{\left(1-\rho^2\right)}\sigma}$$

$$dx_1=dx\sqrt{\left(1-\rho^2\right)}\sigma e^{x\sqrt{\left(1-\rho^2\right)}\sigma}x_2e^{\mu(1-\rho)} \qquad (3.7.13)$$

$p_{x_1x_2}(x_1,x_2)$ se može predstaviti u pogodnijem obliku:

$$p_{x_1x_2}(x_1,x_2)=\frac{1}{\sqrt{2\pi}\sigma x_2}e^{-\frac{(\ln x_2-\mu)^2}{2\sigma^2}}\frac{1}{\sqrt{2\pi}\sigma\sqrt{1-\rho^2}x_1}e^{-\frac{(\ln x_1-(\mu+\rho(\ln x_2-\mu)))^2}{2(1-\rho^2)\sigma^2}} \tag{3.7.14}$$

$$\int_{r_T}^{\infty}p_{x_1x_2}(x_1,x_2)dx_1=\frac{1}{\sqrt{2\pi}\sigma x_2}e^{-\frac{(\ln x_2-\mu)^2}{2\sigma^2}}\int_{r_T}^{\infty}\frac{1}{\sqrt{2\pi}\sigma\sqrt{1-\rho^2}x_1}e^{-\frac{(\ln x_1-(\mu+\rho(\ln x_2-\mu)))^2}{2(1-\rho^2)\sigma^2}}dx_1=$$

$$=\frac{1}{\sqrt{2\pi}\sigma x_2}e^{-\frac{(\ln x_2-\mu)^2}{2\sigma^2}}\cdot\int_{\frac{\ln r_T-\mu(1-\rho)-\rho\ln x_2}{\sqrt{(1-\rho^2)}\sigma}}^{\infty}\frac{\sqrt{(1-\rho^2)}\sigma e^{x\sqrt{(1-\rho^2)}\sigma}x_2e^{\mu(1-\rho)}}{\sqrt{2\pi}\sigma\sqrt{1-\rho^2}e^{x\sqrt{(1-\rho^2)}\sigma}x_2e^{\mu(1-\rho)}}e^{-\frac{x^2}{2}}dx=$$

$$=\frac{1}{\sqrt{2\pi}\sigma x_2}e^{-\frac{(\ln x_2-\mu)^2}{2\sigma^2}}Q\left(\frac{\ln r_T-\mu(1-\rho)-\rho\ln x_2}{\sqrt{(1-\rho^2)}\sigma}\right) \tag{3.7.15}$$

Na osnovu (3.7.15) se dobija:

$$\int_{0}^{r_T}p_{x_1x_2}(x_1,x_2)dx_1=\frac{1}{\sqrt{2\pi}\sigma x_2}e^{-\frac{(\ln x_2-\mu)^2}{2\sigma^2}}\left[1-Q\left(\frac{\ln r_T-\mu(1-\rho)-\rho\ln x_2}{\sigma\sqrt{1-\rho^2}}\right)\right] \tag{3.7.16}$$

Zamenom (3.7.16) u izrazima (3.7.9-12) dobija se konačni oblik za združenu gustinu raspodele verovatnoće na izlazu iz SSC kombinera.

Za $r_1<r_T$, $r_2<r_T$

$$\begin{aligned}p_{r_1r_2}(r_1,r_2)=P_1\frac{1}{\sqrt{2\pi}\sigma_2r_1}e^{-\frac{(\ln r_1-\mu_2)^2}{2\sigma_2^2}}\left[1-Q\left(\frac{\ln r_T-\mu_2(1-\rho_2)-\rho_2\ln r_1}{\sigma_2\sqrt{1-\rho_2^2}}\right)\right]\cdot\\ \cdot\frac{1}{\sqrt{2\pi}\sigma_1r_2}e^{-\frac{(\ln r_2-\mu_1)^2}{2\sigma_1^2}}\left[1-Q\left(\frac{\ln r_T-\mu_1(1-\rho_1)-\rho_1\ln r_2}{\sigma_1\sqrt{1-\rho_1^2}}\right)\right]+\\ +P_2\frac{1}{\sqrt{2\pi}\sigma_1r_1}e^{-\frac{(\ln r_1-\mu_1)^2}{2\sigma_1^2}}\left[1-Q\left(\frac{\ln r_T-\mu_1(1-\rho_1)-\rho_1\ln r_1}{\sigma_1\sqrt{1-\rho_1^2}}\right)\right]\cdot\\ \cdot\frac{1}{\sqrt{2\pi}\sigma_2r_2}e^{-\frac{(\ln r_2-\mu_2)^2}{2\sigma_2^2}}\left[1-Q\left(\frac{\ln r_T-\mu_2(1-\rho_2)-\rho_2\ln r_2}{\sigma_2\sqrt{1-\rho_2^2}}\right)\right]\end{aligned} \tag{3.7.17}$$

Za $r_1\geq r_T$, $r_2<r_T$

$$p_{r_1r_2}(r_1,r_2)=P_1\frac{1}{\sqrt{2\pi}\sigma_1 r_1}e^{-\frac{(\ln r_1-\mu_1)^2}{2\sigma_1^2}}\frac{1}{\sqrt{2\pi}\sigma_2 r_2}e^{-\frac{(\ln r_2-\mu_2)^2}{2\sigma_2^2}}\left[1-Q\left(\frac{\ln r_T-\mu_1(1-\rho_1)-\rho_1\ln r_1}{\sigma_1\sqrt{1-\rho_1^2}}\right)\right]+$$

$$+P_1\frac{1}{\sqrt{2\pi}\sigma_2 r_1}e^{-\frac{(\ln r_1-\mu_2)^2}{2\sigma_2^2}}\left[1-Q\left(\frac{\ln r_T-\mu_2(1-\rho_2)-\rho_2\ln r_1}{\sigma_2\sqrt{1-\rho_2^2}}\right)\right]\cdot$$

$$\cdot\frac{1}{\sqrt{2\pi}\sigma_1 r_2}e^{-\frac{(\ln r_2-\mu_1)^2}{2\sigma_1^2}}\left[1-Q\left(\frac{\ln r_T-\mu_1(1-\rho_1)-\rho_1\ln r_2}{\sigma_1\sqrt{1-\rho_1^2}}\right)\right]+$$

$$+P_2\frac{1}{\sqrt{2\pi}\sigma_2 r_1}e^{-\frac{(\ln r_1-\mu_2)^2}{2\sigma_2^2}}\frac{1}{\sqrt{2\pi}\sigma_1 r_2}e^{-\frac{(\ln r_2-\mu_1)^2}{2\sigma_1^2}}\left[1-Q\left(\frac{\ln r_T-\mu_2(1-\rho_2)-\rho_2\ln r_1}{\sigma_2\sqrt{1-\rho_2^2}}\right)\right]+$$

$$+P_2\frac{1}{\sqrt{2\pi}\sigma_1 r_1}e^{-\frac{(\ln r_1-\mu_1)^2}{2\sigma_1^2}}\left[1-Q\left(\frac{\ln r_T-\mu_1(1-\rho_1)-\rho_1\ln r_1}{\sigma_1\sqrt{1-\rho_1^2}}\right)\right]\cdot$$

$$\cdot\frac{1}{\sqrt{2\pi}\sigma_2 r_2}e^{-\frac{(\ln r_2-\mu_2)^2}{2\sigma_2^2}}\left[1-Q\left(\frac{\ln r_T-\mu_2(1-\rho_2)-\rho_2\ln r_2}{\sigma_2\sqrt{1-\rho_2^2}}\right)\right] \qquad (3.7.18)$$

Za $r_1<r_T$, $r_2\geq r_T$

$$p_{r_1r_2}(r_1,r_2)=$$

$$=P_1\left(1-Q\left(\frac{\ln r_T-\mu_1}{\sigma_1}\right)\right)\frac{1}{2\pi\sigma_2^2\sqrt{1-\rho_2^2}\,r_1r_2}e^{-\frac{1}{2\left(1-\rho_2^2\right)}\left[\left(\frac{\ln r_1-\mu_2}{\sigma_2}\right)^2+\left(\frac{\ln r_2-\mu_2}{\sigma_2}\right)^2-2\rho_2\left(\frac{\ln r_1-\mu_2}{\sigma_2}\right)\left(\frac{\ln r_2-\mu_2}{\sigma_2}\right)\right]}+$$

$$+P_1\frac{1}{\sqrt{2\pi}\sigma_2 r_1}e^{-\frac{(\ln r_1-\mu_2)^2}{2\sigma_2^2}}\left[1-Q\left(\frac{\ln r_T-\mu_2(1-\rho_2)-\rho_2\ln r_1}{\sigma_2\sqrt{1-\rho_2^2}}\right)\right]\cdot$$

$$\cdot\frac{1}{\sqrt{2\pi}\sigma_1 r_2}e^{-\frac{(\ln r_2-\mu_1)^2}{2\sigma_1^2}}\left[1-Q\left(\frac{\ln r_T-\mu_1(1-\rho_1)-\rho_1\ln r_2}{\sigma_1\sqrt{1-\rho_1^2}}\right)\right]+$$

$$+P_2\left(1-Q\left(\frac{\ln r_T-\mu_2}{\sigma_2}\right)\right)\frac{1}{2\pi\sigma_1^2\sqrt{1-\rho_1^2}\,r_1r_2}e^{-\frac{1}{2\left(1-\rho_1^2\right)}\left[\left(\frac{\ln r_1-\mu_1}{\sigma_1}\right)^2+\left(\frac{\ln r_2-\mu_1}{\sigma_1}\right)^2-2\rho_1\left(\frac{\ln r_1-\mu_1}{\sigma_1}\right)\left(\frac{\ln r_2-\mu_1}{\sigma_1}\right)\right]}+$$

$$+P_2\frac{1}{\sqrt{2\pi}\sigma_1 r_1}e^{-\frac{(\ln r_1-\mu_1)^2}{2\sigma_1^2}}\left[1-Q\left(\frac{\ln r_T-\mu_1(1-\rho_1)-\rho_1\ln r_1}{\sigma_1\sqrt{1-\rho_1^2}}\right)\right]\cdot$$

$$\cdot\frac{1}{\sqrt{2\pi}\sigma_2 r_2}e^{-\frac{(\ln r_2-\mu_2)^2}{2\sigma_2^2}}\left[1-Q\left(\frac{\ln r_T-\mu_2(1-\rho_2)-\rho_2\ln r_2}{\sigma_2\sqrt{1-\rho_2^2}}\right)\right] \tag{3.7.19}$$

Za $r_1 \geq r_T$, $r_2 \geq r_T$

$$p_{r_1 r_2}(r_1,r_2)=P_1\frac{1}{2\pi\sigma_1^2\sqrt{1-\rho_1^2}\,r_1 r_2}e^{-\frac{1}{2\left(1-\rho_1^2\right)}\left[\left(\frac{\ln r_1-\mu_1}{\sigma_1}\right)^2+\left(\frac{\ln r_2-\mu_1}{\sigma_1}\right)^2-2\rho_1\left(\frac{\ln r_1-\mu_1}{\sigma_1}\right)\left(\frac{\ln r_2-\mu_1}{\sigma_1}\right)\right]}+$$

$$+P_1\frac{1}{\sqrt{2\pi}\sigma_1 r_1}e^{-\frac{(\ln r_1-\mu_1)^2}{2\sigma_1^2}}\frac{1}{\sqrt{2\pi}\sigma_2 r_2}e^{-\frac{(\ln r_2-\mu_2)^2}{2\sigma_2^2}}\left[1-Q\left(\frac{\ln r_T-\mu_1(1-\rho_1)-\rho_1\ln r_1}{\sigma_1\sqrt{1-\rho_1^2}}\right)\right]+$$

$$+P_1\left(1-Q\left(\frac{\ln r_T-\mu_1}{\sigma_1}\right)\right)\frac{1}{2\pi\sigma_2^2\sqrt{1-\rho_2^2}\,r_1 r_2}e^{-\frac{1}{2\left(1-\rho_2^2\right)}\left[\left(\frac{\ln r_1-\mu_2}{\sigma_2}\right)^2+\left(\frac{\ln r_2-\mu_2}{\sigma_2}\right)^2-2\rho_2\left(\frac{\ln r_1-\mu_2}{\sigma_2}\right)\left(\frac{\ln r_2-\mu_2}{\sigma_2}\right)\right]}+$$

$$+P_1\frac{1}{\sqrt{2\pi}\sigma_2 r_1}e^{-\frac{(\ln r_1-\mu_2)^2}{2\sigma_2^2}}\left[1-Q\left(\frac{\ln r_T-\mu_2(1-\rho_2)-\rho_2\ln r_1}{\sigma_2\sqrt{1-\rho_2^2}}\right)\right]\cdot$$

$$\cdot\frac{1}{\sqrt{2\pi}\sigma_1 r_2}e^{-\frac{(\ln r_2-\mu_1)^2}{2\sigma_1^2}}\left[1-Q\left(\frac{\ln r_T-\mu_1(1-\rho_1)-\rho_1\ln r_2}{\sigma_1\sqrt{1-\rho_1^2}}\right)\right]+$$

$$+P_2\frac{1}{2\pi\sigma_2^2\sqrt{1-\rho_2^2}\,r_1 r_2}e^{-\frac{1}{2\left(1-\rho_2^2\right)}\left[\left(\frac{\ln r_1-\mu_2}{\sigma_2}\right)^2+\left(\frac{\ln r_2-\mu_2}{\sigma_2}\right)^2-2\rho_2\left(\frac{\ln r_1-\mu_2}{\sigma_2}\right)\left(\frac{\ln r_2-\mu_2}{\sigma_2}\right)\right]}+$$

$$+P_2\frac{1}{\sqrt{2\pi}\sigma_2 r_1}e^{-\frac{(\ln r_1-\mu_2)^2}{2\sigma_2^2}}\frac{1}{\sqrt{2\pi}\sigma_1 r_2}e^{-\frac{(\ln r_2-\mu_1)^2}{2\sigma_1^2}}\left[1-Q\left(\frac{\ln r_T-\mu_2(1-\rho_2)-\rho_2\ln r_1}{\sigma_2\sqrt{1-\rho_2^2}}\right)\right]+$$

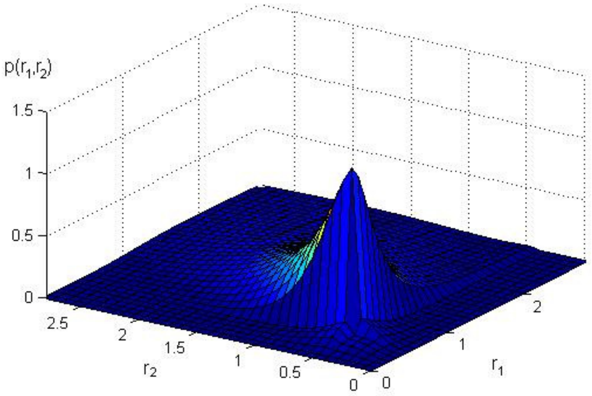
$$+P_2\left(1-Q\left(\frac{\ln r_T-\mu_2}{\sigma_2}\right)\right)\frac{1}{2\pi\sigma_1^2\sqrt{1-\rho_1^2}\,r_1 r_2}e^{-\frac{1}{2\left(1-\rho_1^2\right)}\left[\left(\frac{\ln r_1-\mu_1}{\sigma_1}\right)^2+\left(\frac{\ln r_2-\mu_1}{\sigma_1}\right)^2-2\rho_1\left(\frac{\ln r_1-\mu_1}{\sigma_1}\right)\left(\frac{\ln r_2-\mu_1}{\sigma_1}\right)\right]}+$$

$$+P_2\frac{1}{\sqrt{2\pi}\sigma_1 r_1}e^{-\frac{(\ln r_1-\mu_1)^2}{2\sigma_1^2}}\left[1-Q\left(\frac{\ln r_T-\mu_1(1-\rho_1)-\rho_1\ln r_1}{\sigma_1\sqrt{1-\rho_1^2}}\right)\right]\cdot$$

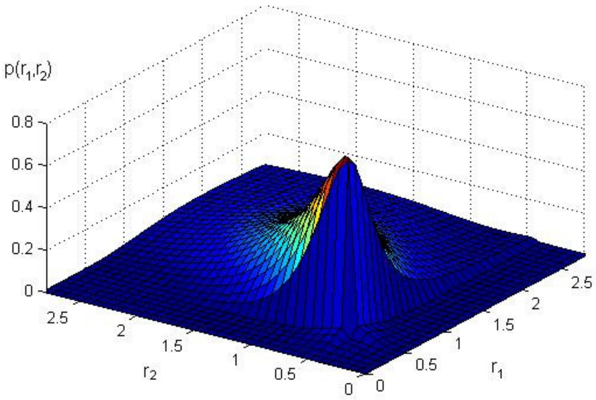
$$\cdot\frac{1}{\sqrt{2\pi}\sigma_2 r_2}e^{-\frac{(\ln r_2-\mu_2)^2}{2\sigma_2^2}}\left[1-Q\left(\frac{\ln r_T-\mu_2(1-\rho_2)-\rho_2\ln r_2}{\sigma_2\sqrt{1-\rho_2^2}}\right)\right] \tag{3.7.20}$$

Združena gustina raspodele verovatnoće na izlazu iz SSC kombinera se može jednostavno predstaviti grafički upotrebom matematičkog softvera kao što je “MatLab”. Radi uproštavanje, ane gubeći uopštenost, pretpostavljeno je da su parametri raspodele isti za obe grane kombinera.

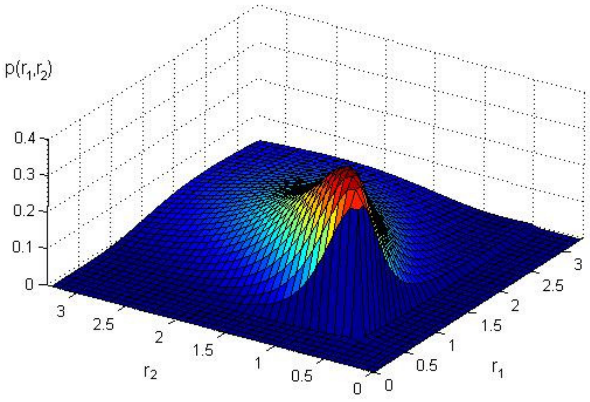
Na slikama 3.7.1.-9. predstavljena je zavisnost PDF od vrednposti signala za različite vrednosti parametara raspodele, korelacije i praga odlučivanja.



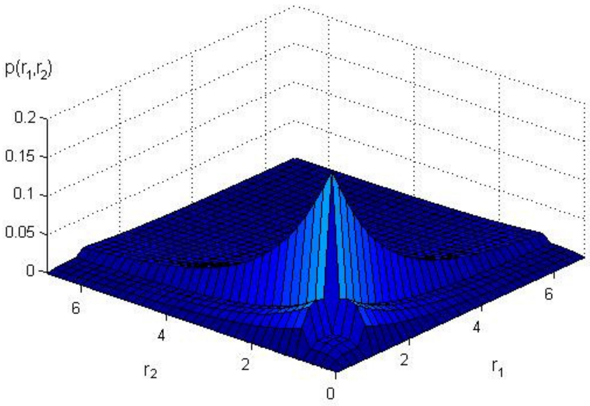
Slika 3.7.1. Združena gustina raspodele verovatnoće na izlazu iz SSC kombinera u dva trenutka vremena u prisustvu log-normalnog fedinga za parametre: $\rho = 0.8$, $r_T = 0.5$, $\sigma = 0.7$, $\mu = 0.1$



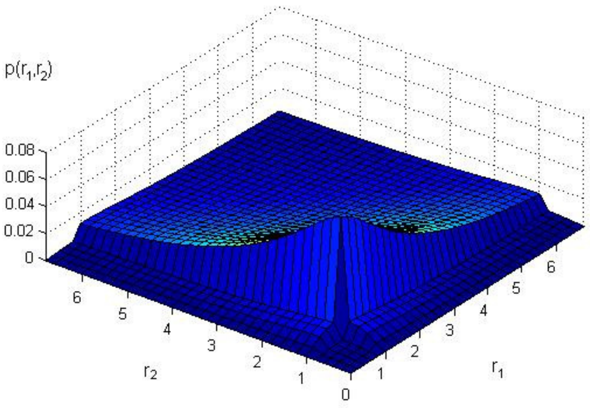
Slika 3.7.2. Združena gustina raspodele verovatnoće na izlazu iz SSC kombinera u dva trenutka vremena u prisustvu log-normalnog fedinga za parametre: $\rho = 0.8$, $r_T = 0.5$, $\sigma = 0.7$, $\mu = 0.3$



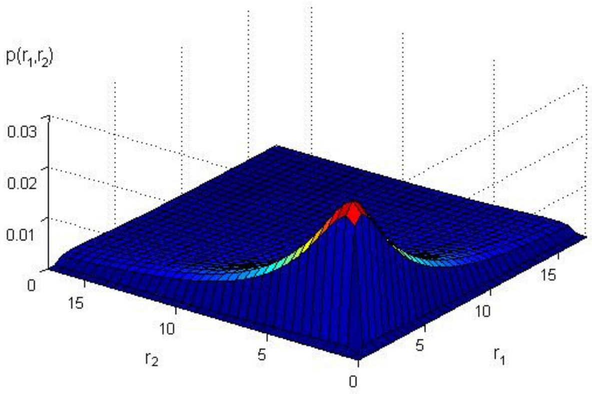
Slika 3.7.3. Združena gustina raspodele verovatnoće na izlazu iz SSC kombinera u dva trenutka vremena u prisustvu log-normalnog fedinga za parametre: $\rho = 0.8$, $r_T = 0.5$, $\sigma = 0.7$, $\mu = 0.6$



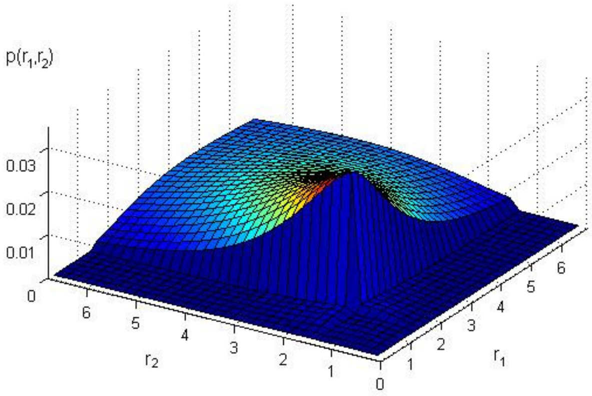
Slika 3.7.4. Združena gustina raspodele verovatnoće na izlazu iz SSC kombinera u dva trenutka vremena u prisustvu log-normalnog fedinga za parametre: $\rho = 0.1$, $r_T = 1$, $\sigma = 1$, $\mu = 0.5$



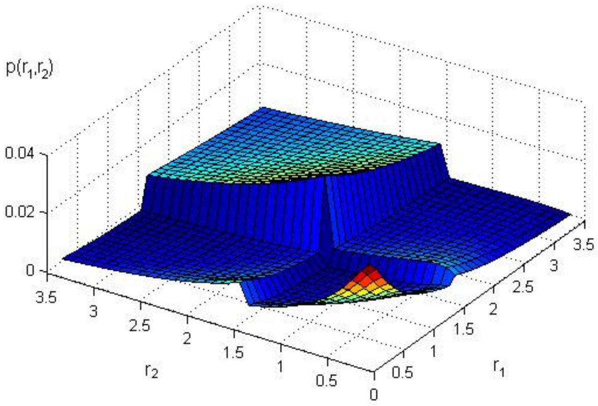
Slika 3.7.5. Združena gustina raspodele verovatnoće na izlazu iz SSC kombinera u dva trenutka vremena u prisustvu log-normalnog fedinga za parametre: $\rho = 0.1$, $r_T = 1$, $\sigma = 1$, $\mu = 1$



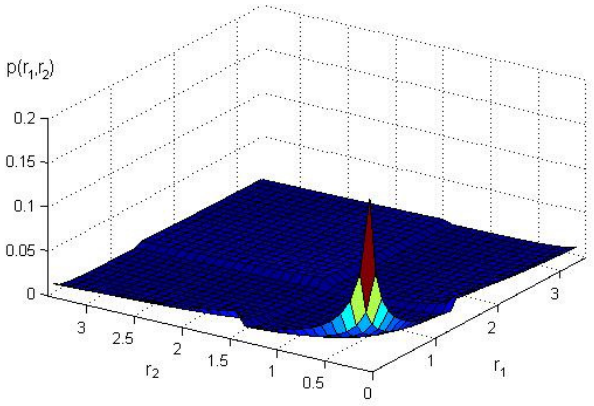
Slika 3.7.6. Združena gustina raspodele verovatnoće na izlazu iz SSC kombinera u dva trenutka vremena u prisustvu log-normalnog fedinga za parametre: $\rho = 0.1$, $r_T = 1$, $\sigma = 1$, $\mu = 1.5$



Slika 3.7.7. Združena gustina raspodele verovatnoće na izlazu iz SSC kombinera u dva trenutka vremena u prisustvu log-normalnog fedinga za parametre: $\rho = 0.8$, $r_T = 1.5$, $\mu = 2$, $\sigma = 1$



Slika 3.7.8. Združena gustina raspodele verovatnoće na izlazu iz SSC kombinera u dva trenutka vremena u prisustvu log-normalnog fedinga za parametre: $\rho = 0.8$, $r_T = 1.5$, $\mu = 2$, $\sigma = 2$



Slika 3.7.9. Združena gustina raspodele verovatnoće na izlazu iz SSC kombinera u dva trenutka vremena u prisustvu log-normalnog fedinga za parametre: $\rho = 0.8$, $r_T = 1.5$, $\mu = 2$, $\sigma = 4$

3.8 Združena gustina raspodele verovatnoće na izlazu SSC kombinera u dva trenutka vremena u prisustvu gamma fedinga

Gustina raspodele verovatnoće i kumulativna raspodela verovatnoće (CDF) signala na izlazu iz kombinera $r_{i,j}$ u prisustvu gamma fedinga su [11]:

$$p_{r_i}(r_{i,j}) = \frac{1}{\Gamma(c_i)} \Omega_i^{-c_i} r_{i,j}^{c_i-1} e^{-\frac{r_{i,j}}{\Omega_i}} \quad , \quad r_{i,j} \geq 0 \tag{3.8.1}$$

$$F_{r_i}(r_{i,j}) = \gamma\left(c_i, \frac{r_{i,j}}{\Omega_i}\right) \quad , \quad r_{i,j} \geq 0 \tag{3.8.2}$$

gde su *i=1,2 j=1,2, c* je red gamma raspodele, *Ω* zavisi od srednje snage signala, a $\gamma(x,a)$ je nekompletna gama funkcija.

Verovatnoće P_1 i P_2 se dobijaju ako se u (3.1.17-18) stavi (3.8.2):

$$P_1 = \frac{F_{r_2}(r_T)}{F_{r_1}(r_T) + F_{r_2}(r_T)} = \frac{\gamma\left(c_2, \frac{r_T}{\Omega_2}\right)}{\gamma\left(c_1, \frac{r_T}{\Omega_1}\right) + \gamma\left(c_2, \frac{r_T}{\Omega_2}\right)} \tag{3.8.3}$$

$$P_2 = \frac{F_{r_1}(r_T)}{F_{r_1}(r_T) + F_{r_2}(r_T)} = \frac{\gamma\left(c_1, \frac{r_T}{\Omega_1}\right)}{\gamma\left(c_1, \frac{r_T}{\Omega_1}\right) + \gamma\left(c_2, \frac{r_T}{\Omega_2}\right)} \tag{3.8.4}$$

Združena gustina raspodele verovatnoće korelisanih signala x_1 i x_2 sa gamma raspodelom i istim parametrima raspodele je [56], [57]:

$$p_{x_1x_2}\left(x_1,x_2\right)=\frac{\rho^{-\frac{c-1}{2}}}{\Gamma(c)(1-\rho)\Omega^{c+1}}\left(x_1x_2\right)^{\frac{c-1}{2}}e^{-\frac{x_1+x_2}{(1-\rho)\Omega}}I_{c-1}\left(\frac{2\sqrt{\rho x_1x_2}}{(1-\rho)\Omega}\right) \qquad (3.8.5)$$

gde je ρ koeficijent korelacije.

Združena gustina raspodele verovatnoće signala r_1 i r_2 na izlazu SSC kombinera u dva trenutka vremena u prisustvu log-normalnog fedinga kada su signali na ulazu u grane kombinera nezavisni, može se dobiti ako se u (3.2.5-8) stave izrazi (3.3.93) i (3.3.97).

Za $r_1<r_T$, $r_2<r_T$

$$\begin{aligned}
p_{r_1r_2}(r_1,r_2)&=P_1\int_0^{r_T}\frac{\rho_1^{-\frac{c_1-1}{2}}}{\Gamma(c_1)(1-\rho_1)\Omega_1^{c_1+1}}\left(r_{11}r_2\right)^{\frac{c_1-1}{2}}e^{-\frac{r_{11}+r_2}{(1-\rho_1)\Omega_1}}I_{c_1-1}\left(\frac{2\sqrt{\rho_1r_{11}r_2}}{(1-\rho_1)\Omega_1}\right)dr_{11}\cdot\\
&\cdot\int_0^{r_T}\frac{\rho_2^{-\frac{c_2-1}{2}}}{\Gamma(c_2)(1-\rho_2)\Omega_2^{c_2+1}}\left(r_{22}r_1\right)^{\frac{c_2-1}{2}}e^{-\frac{r_{22}+r_1}{(1-\rho_2)\Omega_2}}I_{c_2-1}\left(\frac{2\sqrt{\rho_2r_{22}r_1}}{(1-\rho_2)\Omega_2}\right)dr_{22}+\\
&+P_2\int_0^{r_T}\frac{\rho_2^{-\frac{c_2-1}{2}}}{\Gamma(c_2)(1-\rho_2)\Omega_2^{c_2+1}}\left(r_{21}r_2\right)^{\frac{c_2-1}{2}}e^{-\frac{r_{21}+r_2}{(1-\rho_2)\Omega_2}}I_{c_2-1}\left(\frac{2\sqrt{\rho_2r_{21}r_2}}{(1-\rho_2)\Omega_2}\right)dr_{21}\cdot\\
&\cdot\int_0^{r_T}\frac{\rho_1^{-\frac{c_1-1}{2}}}{\Gamma(c_1)(1-\rho_1)\Omega_1^{c_1+1}}\left(r_{12}r_1\right)^{\frac{c_1-1}{2}}e^{-\frac{r_{12}+r_1}{(1-\rho_1)\Omega_1}}I_{c_1-1}\left(\frac{2\sqrt{\rho_1r_{12}r_1}}{(1-\rho_1)\Omega_1}\right)dr_{12} \qquad (3.8.6)
\end{aligned}$$

Za $r_1\geq r_T$, $r_2<r_T$

$$\begin{aligned}
p_{r_1r_2}(r_1,r_2)&=P_1\frac{1}{\Gamma(c_2)}\Omega_2^{-c_2}r_2^{c_2-1}e^{-\frac{r_2}{\Omega_2}}\int_0^{r_T}\frac{\rho_1^{-\frac{c_1-1}{2}}}{\Gamma(c_1)(1-\rho_1)\Omega_1^{c_1+1}}\left(r_{12}r_1\right)^{\frac{c_1-1}{2}}e^{-\frac{r_{12}+r_1}{(1-\rho_1)\Omega_1}}I_{c_1-1}\left(\frac{2\sqrt{\rho_1r_{12}r_1}}{(1-\rho_1)\Omega_1}\right)dr_{12}+\\
&+P_1\int_0^{r_T}\frac{\rho_1^{-\frac{c_1-1}{2}}}{\Gamma(c_1)(1-\rho_1)\Omega_1^{c_1+1}}\left(r_{11}r_2\right)^{\frac{c_1-1}{2}}e^{-\frac{r_{11}+r_2}{(1-\rho_1)\Omega_1}}I_{c_1-1}\left(\frac{2\sqrt{\rho_1r_{11}r_2}}{(1-\rho_1)\Omega_1}\right)dr_{11}\cdot\\
&\cdot\int_0^{r_T}\frac{\rho_2^{-\frac{c_2-1}{2}}}{\Gamma(c_2)(1-\rho_2)\Omega_2^{c_2+1}}\left(r_{22}r_1\right)^{\frac{c_2-1}{2}}e^{-\frac{r_{22}+r_1}{(1-\rho_2)\Omega_2}}I_{c_2-1}\left(\frac{2\sqrt{\rho_2r_{22}r_1}}{(1-\rho_2)\Omega_2}\right)dr_{22}+\\
&+P_2\frac{1}{\Gamma(c_1)}\Omega_1^{-c_1}r_2^{c_1-1}e^{-\frac{r_2}{\Omega_1}}\int_0^{r_T}\frac{\rho_2^{-\frac{c_2-1}{2}}}{\Gamma(c_2)(1-\rho_2)\Omega_2^{c_2+1}}\left(r_{22}r_1\right)^{\frac{c_2-1}{2}}e^{-\frac{r_{22}+r_1}{(1-\rho_2)\Omega_2}}I_{c_2-1}\left(\frac{2\sqrt{\rho_2r_{22}r_1}}{(1-\rho_2)\Omega_2}\right)dr_{22}+\\
&+P_2\int_0^{r_T}\frac{\rho_2^{-\frac{c_2-1}{2}}}{\Gamma(c_2)(1-\rho_2)\Omega_2^{c_2+1}}\left(r_{21}r_2\right)^{\frac{c_2-1}{2}}e^{-\frac{r_{21}+r_2}{(1-\rho_2)\Omega_2}}I_{c_2-1}\left(\frac{2\sqrt{\rho_2r_{21}r_2}}{(1-\rho_2)\Omega_2}\right)dr_{21}\cdot
\end{aligned}$$

$$\cdot\int_0^{r_T}\frac{\rho_1^{-\frac{c_1-1}{2}}}{\Gamma(c_1)(1-\rho_1)\Omega_1^{c_1+1}}\left(r_{12}r_1\right)^{\frac{c_1-1}{2}}e^{-\frac{r_{12}+r_1}{(1-\rho_1)\Omega_1}}I_{c_1-1}\left(\frac{2\sqrt{\rho_1 r_{12}r_1}}{(1-\rho_1)\Omega_1}\right)dr_{12} \tag{3.8.7}$$

Za $r_1<r_T$, $r_2\geq r_T$

$$p_{r_1r_2}(r_1,r_2)=P_1\gamma\left(c_1,\frac{r_T}{\Omega_1}\right)\frac{\rho_2^{-\frac{c_2-1}{2}}}{\Gamma(c_2)(1-\rho_2)\Omega_2^{c_2+1}}\left(r_1r_2\right)^{\frac{c_2-1}{2}}e^{-\frac{r_1+r_2}{(1-\rho_2)\Omega_2}}I_{c_2-1}\left(\frac{2\sqrt{\rho_2 r_1r_2}}{(1-\rho_2)\Omega_2}\right)+$$

$$+P_1\int_0^{r_T}\frac{\rho_1^{-\frac{c_1-1}{2}}}{\Gamma(c_1)(1-\rho_1)\Omega_1^{c_1+1}}\left(r_{11}r_2\right)^{\frac{c_1-1}{2}}e^{-\frac{r_{11}+r_2}{(1-\rho_1)\Omega_1}}I_{c_1-1}\left(\frac{2\sqrt{\rho_1 r_{11}r_2}}{(1-\rho_1)\Omega_1}\right)dr_{11}\cdot$$

$$\cdot\int_0^{r_T}\frac{\rho_2^{-\frac{c_2-1}{2}}}{\Gamma(c_2)(1-\rho_2)\Omega_2^{c_2+1}}\left(r_{22}r_1\right)^{\frac{c_2-1}{2}}e^{-\frac{r_{22}+r_1}{(1-\rho_2)\Omega_2}}I_{c_2-1}\left(\frac{2\sqrt{\rho_2 r_{22}r_1}}{(1-\rho_2)\Omega_2}\right)dr_{22}+$$

$$+P_2\gamma\left(c_2,\frac{r_T}{\Omega_2}\right)\frac{\rho_1^{-\frac{c_1-1}{2}}}{\Gamma(c_1)(1-\rho_1)\Omega_1^{c_1+1}}\left(r_1r_2\right)^{\frac{c_1-1}{2}}e^{-\frac{r_1+r_2}{(1-\rho_1)\Omega_1}}I_{c_1-1}\left(\frac{2\sqrt{\rho_1 r_1r_2}}{(1-\rho_1)\Omega_1}\right)+$$

$$+P_2\int_0^{r_T}\frac{\rho_2^{-\frac{c_2-1}{2}}}{\Gamma(c_2)(1-\rho_2)\Omega_2^{c_2+1}}\left(r_{21}r_2\right)^{\frac{c_2-1}{2}}e^{-\frac{r_{21}+r_2}{(1-\rho_2)\Omega_2}}I_{c_2-1}\left(\frac{2\sqrt{\rho_2 r_{21}r_2}}{(1-\rho_2)\Omega_2}\right)dr_{21}\cdot$$

$$\cdot\int_0^{r_T}\frac{\rho_1^{-\frac{c_1-1}{2}}}{\Gamma(c_1)(1-\rho_1)\Omega_1^{c_1+1}}\left(r_{12}r_1\right)^{\frac{c_1-1}{2}}e^{-\frac{r_{12}+r_1}{(1-\rho_1)\Omega_1}}I_{c_1-1}\left(\frac{2\sqrt{\rho_1 r_{12}r_1}}{(1-\rho_1)\Omega_1}\right)dr_{12} \tag{3.8.8}$$

Za $r_1\geq r_T$, $r_2\geq r_T$

$$p_{r_1r_2}(r_1,r_2)=P_1\frac{\rho_1^{-\frac{c_1-1}{2}}}{\Gamma(c_1)(1-\rho_1)\Omega_1^{c_1+1}}\left(r_1r_2\right)^{\frac{c_1-1}{2}}e^{-\frac{r_1+r_2}{(1-\rho_1)\Omega_1}}I_{c_1-1}\left(\frac{2\sqrt{\rho_1 r_1r_2}}{(1-\rho_1)\Omega_1}\right)+$$

$$+P_1\frac{1}{\Gamma(c_2)}\Omega_2^{-c_2}r_2^{c_2-1}e^{-\frac{r_2}{\Omega_2}}\int_0^{r_T}\frac{\rho_2^{-\frac{c_1-1}{2}}}{\Gamma(c_1)(1-\rho_2)\Omega_1^{c_1+1}}\left(r_{12}r_1\right)^{\frac{c_1-1}{2}}e^{-\frac{r_{12}+r_1}{(1-\rho_2)\Omega_1}}I_{c_1-1}\left(\frac{2\sqrt{\rho_2 r_{12}r_1}}{(1-\rho_2)\Omega_1}\right)dr_{12}+$$

$$+P_1\gamma\left(c_1,\frac{r_T}{\Omega_1}\right)\frac{\rho_2^{-\frac{c_2-1}{2}}}{\Gamma(c_2)(1-\rho_2)\Omega_2^{c_2+1}}\left(r_1r_2\right)^{\frac{c_2-1}{2}}e^{-\frac{r_1+r_2}{(1-\rho_2)\Omega_2}}I_{c_2-1}\left(\frac{2\sqrt{\rho_2 r_1r_2}}{(1-\rho_2)\Omega_2}\right)+$$

$$+P_1\int_0^{r_T}\frac{\rho_1^{-\frac{c_1-1}{2}}}{\Gamma(c_1)(1-\rho_1)\Omega_1^{c_1+1}}\left(r_{11}r_2\right)^{\frac{c_1-1}{2}}e^{-\frac{r_{11}+r_2}{(1-\rho_1)\Omega_1}}I_{c_1-1}\left(\frac{2\sqrt{\rho_1 r_{11}r_2}}{(1-\rho_1)\Omega_1}\right)dr_{11}\cdot$$

$$\cdot\int_0^{r_T}\frac{\rho_2^{-\frac{c_2-1}{2}}}{\Gamma(c_2)(1-\rho_2)\Omega_2^{c_2+1}}\left(r_{22}r_1\right)^{\frac{c_2-1}{2}}e^{-\frac{r_{22}+r_1}{(1-\rho_2)\Omega_2}}I_{c_2-1}\left(\frac{2\sqrt{\rho_2 r_{22}r_1}}{(1-\rho_2)\Omega_2}\right)dr_{22}+$$

$$+P_2\frac{\rho_2^{-\frac{c_2-1}{2}}}{\Gamma(c_2)(1-\rho_2)\Omega_2^{c_2+1}}\left(r_1r_2\right)^{\frac{c_2-1}{2}}e^{-\frac{r_1+r_2}{(1-\rho_2)\Omega_2}}I_{c_2-1}\left(\frac{2\sqrt{\rho_2 r_1r_2}}{(1-\rho_2)\Omega_2}\right)+$$

$$+P_2\frac{1}{\Gamma(c_1)}\Omega_1^{-c_1}r_2^{c_1-1}e^{-\frac{r_2}{\Omega_1}}\int_0^{r_T}\frac{\rho_1^{-\frac{c_2-1}{2}}}{\Gamma(c_2)(1-\rho_1)\Omega_2^{c_2+1}}\left(r_{22}r_1\right)^{\frac{c_2-1}{2}}e^{-\frac{r_{22}+r_1}{(1-\rho_1)\Omega_2}}I_{c_2-1}\left(\frac{2\sqrt{\rho_1 r_{22}r_1}}{(1-\rho_1)\Omega_2}\right)dr_{22}+$$

$$+P_2\gamma\left(c_2,\frac{r_T}{\Omega_2}\right)\frac{\rho_1^{-\frac{c_1-1}{2}}}{\Gamma(c_1)(1-\rho_1)\Omega_1^{c_1+1}}\left(r_1r_2\right)^{\frac{c_1-1}{2}}e^{-\frac{r_1+r_2}{(1-\rho_1)\Omega_1}}I_{c_1-1}\left(\frac{2\sqrt{\rho_1 r_1r_2}}{(1-\rho_1)\Omega_1}\right)+$$

$$+P_2\int_0^{r_T}\frac{\rho_2^{-\frac{c_2-1}{2}}}{\Gamma(c_2)(1-\rho_2)\Omega_2^{c_2+1}}\left(r_{21}r_2\right)^{\frac{c_2-1}{2}}e^{-\frac{r_{21}+r_2}{(1-\rho_2)\Omega_2}}I_{c_2-1}\left(\frac{2\sqrt{\rho_2 r_{21}r_2}}{(1-\rho_2)\Omega_2}\right)dr_{21}\cdot$$

$$\cdot\int_0^{r_T}\frac{\rho_1^{-\frac{c_1-1}{2}}}{\Gamma(c_1)(1-\rho_1)\Omega_1^{c_1+1}}\left(r_{12}r_1\right)^{\frac{c_1-1}{2}}e^{-\frac{r_{12}+r_1}{(1-\rho_1)\Omega_1}}I_{c_1-1}\left(\frac{2\sqrt{\rho_1 r_{12}r_1}}{(1-\rho_1)\Omega_1}\right)dr_{12} \tag{3.8.9}$$

Izrazi (3.3.98-101) su u obliku jednostrukog integrala sa konačnim granicama.

Združena gustina raspodele verovatnoće se može dobiti u zatvorenom obliku korišćenjem generalizovane Marcum-ove Q-funkcije m-tog reda, gde je m pozitivan ceo broj, što nije ozbiljno ograničenje, jer ako m nije ceo broj, ova formula se može upotrebiti za $\lfloor m \rfloor$ i $\lfloor m+1 \rfloor$ za dobijanje donje i gornje granice, kao i u slucaju Nakagami m fedinga.

Za predstavljanje združene PDF u zatvorenom obliku potrebno je rešiti integral $\int_{r_T}^{\infty} p_{x_1x_2}(x_1,x_2)dx_1$, gde je $p_{x_1x_2}(x_1,x_2)$ dato u (3.3.97). Transformacijom $p_{x_1x_2}(x_1,x_2)$, ona se može predstaviti u obliku koji u podintegralnom delu predstavlja podintegralni deo generalizovane Marcum-ove Q-funkcije m-tog reda.

$$x_1=\frac{x^2\Omega(1-\rho)}{2} \qquad x=\frac{\sqrt{2x_1}}{\sqrt{\Omega(1-\rho)}} \qquad dx_1=x\Omega(1-\rho)dx \tag{3.8.10}$$

$$x_2=\frac{a^2\Omega(1-\rho)}{2\rho} \qquad a=\frac{\sqrt{2\rho x_2}}{\sqrt{\Omega(1-\rho)}} \tag{3.8.11}$$

$$\int_{r_T}^{\infty}p_{x_1x_2}(x_1,x_2)dx_1=\frac{\rho^{-\frac{c-1}{2}}}{\Gamma(c)(1-\rho)\Omega^{c+1}}\int_{r_t}^{\infty}\left(x_1x_2\right)^{\frac{c-1}{2}}e^{-\frac{x_1+x_2}{(1-\rho)\Omega}}I_{c-1}\left(\frac{2\sqrt{\rho x_1x_2}}{\Omega(1-\rho)}\right)dx_1=$$

$$=\frac{1}{\Gamma(c)}\Omega^{-c}x_2^{c-1}e^{-\frac{x_2}{\Omega}}\frac{1}{a^{c-1}}\int_{\frac{\sqrt{2r_t}}{\sqrt{\Omega(1-\rho)}}}^{\infty}x^c e^{-\left(\frac{x^2}{2}+\frac{a^2}{2}\right)}I_{c-1}\left(xa\right)dx=$$

$$=\frac{1}{\Gamma(c)}\Omega^{-c}x_2^{c-1}e^{-\frac{x_2}{\Omega}}Q_c\left(\frac{\sqrt{2\rho x_2}}{\sqrt{\Omega(1-\rho)}},\frac{\sqrt{2r_t}}{\sqrt{\Omega(1-\rho)}}\right) \tag{3.8.12}$$

Na osnovu (3.8.13) se dobija:

$$\int_0^{r_T} p_{x_1x_2}(x_1,x_2)dx_1 = \frac{1}{\Gamma(c)}\Omega^{-c}x_2^{c-1}e^{-\frac{x_2}{\Omega}}\left[1-Q_c\left(\frac{\sqrt{2\rho x_2}}{\sqrt{\Omega(1-\rho)}},\frac{\sqrt{2r_t}}{\sqrt{\Omega(1-\rho)}}\right)\right] \tag{3.8.13}$$

Zamenom (3.8.13) u izrazima (3.8.6-9) dobija se konačni oblik za združenu gustinu raspodele verovatnoće na izlazu iz SSC kombinera.

Za $r_1<r_T$, $r_2<r_T$

$$\begin{aligned}
p_{r_1r_2}(r_1,r_2) = {} & P_1\frac{1}{\Gamma(c_2)}\Omega_2^{-c_2}r_1^{c_2-1}e^{-\frac{r_1}{\Omega_2}}\left[1-Q_{c_2}\left(\frac{\sqrt{2\rho_2 r_1}}{\sqrt{\Omega_2(1-\rho_2)}},\frac{\sqrt{2r_T}}{\sqrt{\Omega_2(1-\rho_2)}}\right)\right]\cdot \\
& \cdot\frac{1}{\Gamma(c_1)}\Omega_1^{-c_1}r_2^{c_1-1}e^{-\frac{r_2}{\Omega_1}}\left[1-Q_{c_1}\left(\frac{\sqrt{2\rho_1 r_2}}{\sqrt{\Omega_1(1-\rho_1)}},\frac{\sqrt{2r_T}}{\sqrt{\Omega_1(1-\rho_1)}}\right)\right]+ \\
& +P_2\frac{1}{\Gamma(c_1)}\Omega_1^{-c_1}r_1^{c_1-1}e^{-\frac{r_1}{\Omega_1}}\left[1-Q_{c_1}\left(\frac{\sqrt{2\rho_1 r_1}}{\sqrt{\Omega_1(1-\rho_1)}},\frac{\sqrt{2r_T}}{\sqrt{\Omega_1(1-\rho_1)}}\right)\right]\cdot \\
& \cdot\frac{1}{\Gamma(c_2)}\Omega_2^{-c_2}r_2^{c_2-1}e^{-\frac{r_2}{\Omega_2}}\left[1-Q_{c_2}\left(\frac{\sqrt{2\rho_2 r_2}}{\sqrt{\Omega_2(1-\rho_2)}},\frac{\sqrt{2r_T}}{\sqrt{\Omega_2(1-\rho_2)}}\right)\right]
\end{aligned} \tag{3.8.14}$$

Za $r_1\geq r_T$, $r_2<r_T$

$$\begin{aligned}
p_{r_1r_2}(r_1,r_2) = {} & P_1\frac{1}{\Gamma(c_1)}\Omega_1^{-c_1}r_1^{c_1-1}e^{-\frac{r_1}{\Omega_1}}\frac{1}{\Gamma(c_2)}\Omega_2^{-c_2}r_2^{c_2-1}e^{-\frac{r_2}{\Omega_2}}\left[1-Q_{c_1}\left(\frac{\sqrt{2\rho_1 r_1}}{\sqrt{\Omega_1(1-\rho_1)}},\frac{\sqrt{2r_T}}{\sqrt{\Omega_1(1-\rho_1)}}\right)\right]+ \\
& +P_1\frac{1}{\Gamma(c_2)}\Omega_2^{-c_2}r_1^{c_2-1}e^{-\frac{r_1}{\Omega_2}}\left[1-Q_{c_2}\left(\frac{\sqrt{2\rho_2 r_1}}{\sqrt{\Omega_2(1-\rho_2)}},\frac{\sqrt{2r_T}}{\sqrt{\Omega_2(1-\rho_2)}}\right)\right]\cdot \\
& \cdot\frac{1}{\Gamma(c_1)}\Omega_1^{-c_1}r_2^{c_1-1}e^{-\frac{r_2}{\Omega_1}}\left[1-Q_{c_1}\left(\frac{\sqrt{2\rho_1 r_2}}{\sqrt{\Omega_1(1-\rho_1)}},\frac{\sqrt{2r_T}}{\sqrt{\Omega_1(1-\rho_1)}}\right)\right]+ \\
& +P_2\frac{1}{\Gamma(c_2)}\Omega_2^{-c_2}r_1^{c_2-1}e^{-\frac{r_1}{\Omega_2}}\frac{1}{\Gamma(c_1)}\Omega_1^{-c_1}r_2^{c_1-1}e^{-\frac{r_2}{\Omega_1}}\left[1-Q_{c_2}\left(\frac{\sqrt{2\rho_2 r_1}}{\sqrt{\Omega_2(1-\rho_2)}},\frac{\sqrt{2r_T}}{\sqrt{\Omega_2(1-\rho_2)}}\right)\right]\cdot \\
& +P_2\frac{1}{\Gamma(c_1)}\Omega_1^{-c_1}r_1^{c_1-1}e^{-\frac{r_1}{\Omega_1}}\left[1-Q_{c_1}\left(\frac{\sqrt{2\rho_1 r_1}}{\sqrt{\Omega_1(1-\rho_1)}},\frac{\sqrt{2r_T}}{\sqrt{\Omega_1(1-\rho_1)}}\right)\right]\cdot \\
& \cdot\frac{1}{\Gamma(c_2)}\Omega_2^{-c_2}r_2^{c_2-1}e^{-\frac{r_2}{\Omega_2}}\left[1-Q_{c_2}\left(\frac{\sqrt{2\rho_2 r_2}}{\sqrt{\Omega_2(1-\rho_2)}},\frac{\sqrt{2r_T}}{\sqrt{\Omega_2(1-\rho_2)}}\right)\right]
\end{aligned} \tag{3.8.15}$$

Za $r_1<r_T$, $r_2\geq r_T$

$$p_{r_1r_2}(r_1,r_2)=P_1\gamma\left(c_1,\frac{r_T}{\Omega_1}\right)\frac{\rho_2^{-\frac{c_2-1}{2}}}{\Gamma(c_2)(1-\rho_2)\Omega_2^{c_2+1}}\left(r_1r_2\right)^{\frac{c_2-1}{2}}e^{-\frac{r_1+r_2}{(1-\rho_2)\Omega_2}}I_{c_2-1}\left(\frac{2\sqrt{\rho_2r_1r_2}}{(1-\rho_2)\Omega_2}\right)+$$

$$+P_1\frac{1}{\Gamma(c_2)}\Omega_2^{-c_2}r_1^{c_2-1}e^{-\frac{r_1}{\Omega_2}}\left[1-Q_{c_2}\left(\frac{\sqrt{2\rho_2r_1}}{\sqrt{\Omega_2(1-\rho_2)}},\frac{\sqrt{2r_T}}{\sqrt{\Omega_2(1-\rho_2)}}\right)\right]\cdot$$

$$\cdot\frac{1}{\Gamma(c_1)}\Omega_1^{-c_1}r_2^{c_1-1}e^{-\frac{r_2}{\Omega_1}}\left[1-Q_{c_1}\left(\frac{\sqrt{2\rho_1r_2}}{\sqrt{\Omega_1(1-\rho_1)}},\frac{\sqrt{2r_T}}{\sqrt{\Omega_1(1-\rho_1)}}\right)\right]+$$

$$+P_2\gamma\left(c_2,\frac{r_T}{\Omega_2}\right)\frac{\rho_1^{-\frac{c_1-1}{2}}}{\Gamma(c_1)(1-\rho_1)\Omega_1^{c_1+1}}\left(r_1r_2\right)^{\frac{c_1-1}{2}}e^{-\frac{r_1+r_2}{(1-\rho_1)\Omega_1}}I_{c_1-1}\left(\frac{2\sqrt{\rho_1r_1r_2}}{(1-\rho_1)\Omega_1}\right)+$$

$$+P_2\frac{1}{\Gamma(c_1)}\Omega_1^{-c_1}r_1^{c_1-1}e^{-\frac{r_1}{\Omega_1}}\left[1-Q_{c_1}\left(\frac{\sqrt{2\rho_1r_1}}{\sqrt{\Omega_1(1-\rho_1)}},\frac{\sqrt{2r_T}}{\sqrt{\Omega_1(1-\rho_1)}}\right)\right]\cdot$$

$$\cdot\frac{1}{\Gamma(c_2)}\Omega_2^{-c_2}r_2^{c_2-1}e^{-\frac{r_2}{\Omega_2}}\left[1-Q_{c_2}\left(\frac{\sqrt{2\rho_2r_2}}{\sqrt{\Omega_2(1-\rho_2)}},\frac{\sqrt{2r_T}}{\sqrt{\Omega_2(1-\rho_2)}}\right)\right]\qquad(3.8.16)$$

Za $r_1 \geq r_T$, $r_2 \geq r_T$

$$p_{r_1r_2}(r_1,r_2)=P_1\frac{\rho^{-\frac{c_1-1}{2}}}{\Gamma(c_1)(1-\rho_1)\Omega_1^{c_1+1}}\left(r_1r_2\right)^{\frac{c_1-1}{2}}e^{-\frac{r_1+r_2}{(1-\rho_1)\Omega_1}}I_{c_1-1}\left(\frac{2\sqrt{\rho_1r_1r_2}}{(1-\rho_1)\Omega_1}\right)+$$

$$+P_1\frac{1}{\Gamma(c_1)}\Omega_1^{-c_1}r_1^{c_1-1}e^{-\frac{r_1}{\Omega_1}}\frac{1}{\Gamma(c_2)}\Omega_2^{-c_2}r_2^{c_2-1}e^{-\frac{r_2}{\Omega_2}}\left[1-Q_{c_1}\left(\frac{\sqrt{2\rho_1r_1}}{\sqrt{\Omega_1(1-\rho_1)}},\frac{\sqrt{2r_T}}{\sqrt{\Omega_1(1-\rho_1)}}\right)\right]+$$

$$+P_1\gamma\left(c_1,\frac{r_T}{\Omega_1}\right)\frac{\rho_2^{-\frac{c_2-1}{2}}}{\Gamma(c_2)(1-\rho_2)\Omega_2^{c_2+1}}\left(r_1r_2\right)^{\frac{c_2-1}{2}}e^{-\frac{r_1+r_2}{(1-\rho_2)\Omega_2}}I_{c_2-1}\left(\frac{2\sqrt{\rho_2r_1r_2}}{(1-\rho_2)\Omega_2}\right)+$$

$$+P_1\frac{1}{\Gamma(c_2)}\Omega_2^{-c_2}r_1^{c_2-1}e^{-\frac{r_1}{\Omega_2}}\left[1-Q_{c_2}\left(\frac{\sqrt{2\rho_2r_1}}{\sqrt{\Omega_2(1-\rho_2)}},\frac{\sqrt{2r_T}}{\sqrt{\Omega_2(1-\rho_2)}}\right)\right]\cdot$$

$$\cdot\frac{1}{\Gamma(c_1)}\Omega_1^{-c_1}r_2^{c_1-1}e^{-\frac{r_2}{\Omega_1}}\left[1-Q_{c_1}\left(\frac{\sqrt{2\rho_1r_2}}{\sqrt{\Omega_1(1-\rho_1)}},\frac{\sqrt{2r_T}}{\sqrt{\Omega_1(1-\rho_1)}}\right)\right]+$$

$$+P_2\frac{\rho_2^{-\frac{c_2-1}{2}}}{\Gamma(c_2)(1-\rho_2)\Omega_2^{c_2+1}}\left(r_1r_2\right)^{\frac{c_2-1}{2}}e^{-\frac{r_1+r_2}{(1-\rho_2)\Omega_2}}I_{c_2-1}\left(\frac{2\sqrt{\rho_2r_1r_2}}{(1-\rho_2)\Omega_2}\right)+$$

$$+P_2\frac{1}{\Gamma(c_2)}\Omega_2^{-c_2}r_1^{c_2-1}e^{-\frac{r_1}{\Omega_2}}\frac{1}{\Gamma(c_1)}\Omega_1^{-c_1}r_2^{c_1-1}e^{-\frac{r_2}{\Omega_1}}\left[1-Q_{c_2}\left(\frac{\sqrt{2\rho_2r_1}}{\sqrt{\Omega_2(1-\rho_2)}},\frac{\sqrt{2r_T}}{\sqrt{\Omega_2(1-\rho_2)}}\right)\right]+$$

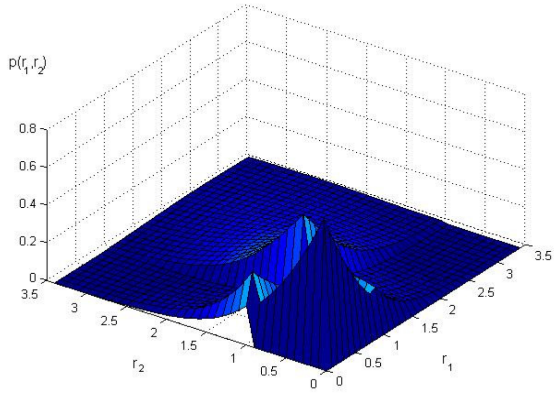
$$P_2\gamma\left(c_2,\frac{r_T}{\Omega_2}\right)\frac{\rho_1^{-\frac{c_1-1}{2}}}{\Gamma(c_1)(1-\rho_1)\Omega_1^{c_1+1}}\left(r_1r_2\right)^{\frac{c_1-1}{2}}e^{-\frac{r_1+r_2}{(1-\rho_1)\Omega_1}}I_{c_1-1}\left(\frac{2\sqrt{\rho_1r_1r_2}}{(1-\rho_1)\Omega_1}\right)+$$

$$+P_2\frac{1}{\Gamma(c_1)}\Omega_1^{-c_1}r_1^{c_1-1}e^{-\frac{r_1}{\Omega_1}}\left[1-Q_{c_1}\left(\frac{\sqrt{2\rho_1r_1}}{\sqrt{\Omega_1(1-\rho_1)}},\frac{\sqrt{2r_T}}{\sqrt{\Omega_1(1-\rho_1)}}\right)\right]\cdot$$

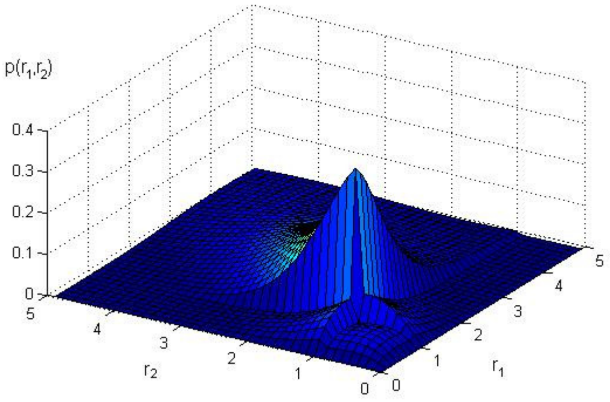
$$\cdot\frac{1}{\Gamma(c_2)}\Omega_2^{-c_2}r_2^{c_2-1}e^{-\frac{r_2}{\Omega_2}}\left[1-Q_{c_2}\left(\frac{\sqrt{2\rho_2r_2}}{\sqrt{\Omega_2(1-\rho_2)}},\frac{\sqrt{2r_T}}{\sqrt{\Omega_2(1-\rho_2)}}\right)\right] \qquad (3.8.17)$$

Radi uproštavanje, a ne gubeći uopštenost, pretpostavljeno je da su parametri raspodele isti za obe grane kombinera.

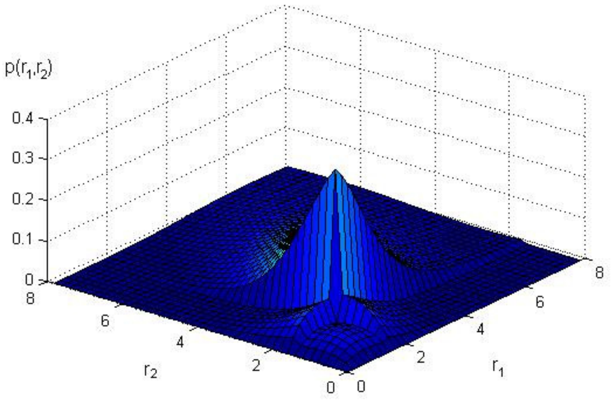
Na slikama 3.8.1.-9. predstavljena je zavisnost PDF od vrednosti signala za različite vrednosti parametara raspodele, korelacije i praga odlučivanja, gde je zbog lakšeg proračuna usvojeno da su parametri raspodele isti za obe grane kombinera.



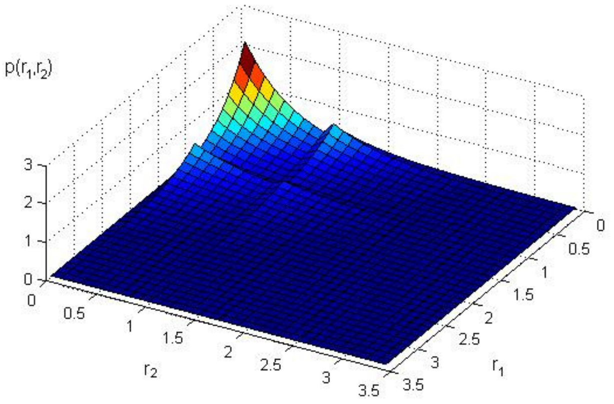
Slika 3.8.1. Združena gustina raspodele verovatnoće na izlazu iz SSC kombinera u dva trenutka vremena u prisustvu gamma fedinga za parametre: $\rho=0.8$, $r_T=1$, $\Omega=1$, $c=1$



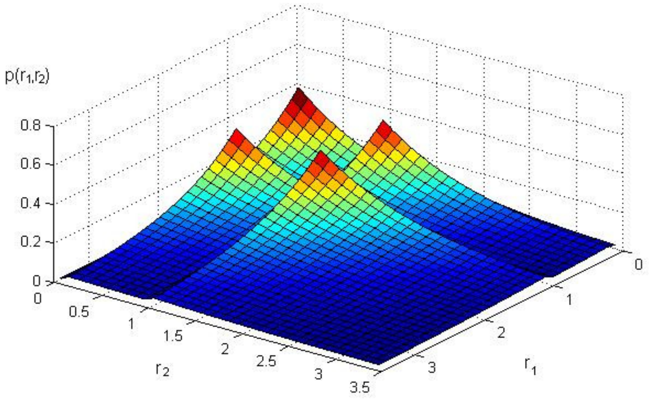
Slika 3.8.2. Združena gustina raspodele verovatnoće na izlazu iz SSC kombinera u dva trenutka vremena u prisustvu gamma fedinga za parametre: $\rho=0.8$, $r_T=1$, $\Omega=1$, $c=2$



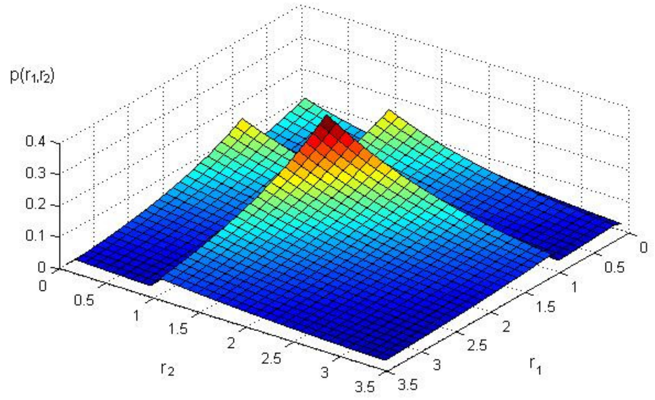
Slika 3.8.3. Združena gustina raspodele verovatnoće na izlazu iz SSC kombinera u dva trenutka vremena u prisustvu gamma fedinga za parametre: $\rho = 0.8$, $r_T = 1$, $\Omega = 1$, $c = 3$



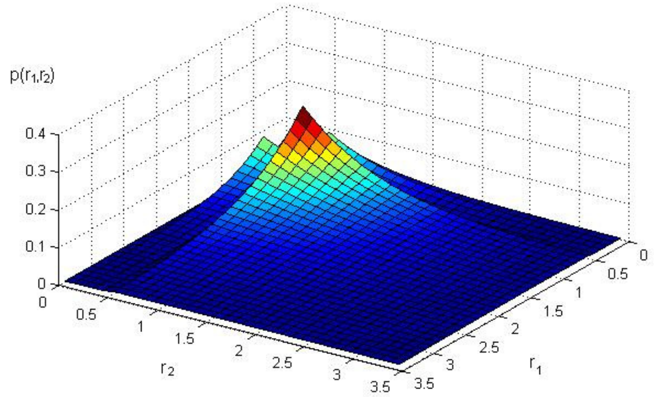
Slika 3.8.4. Združena gustina raspodele verovatnoće na izlazu iz SSC kombinera u dva trenutka vremena u prisustvu gamma fedinga za parametre: $\rho = 0.2$, $r_T = 1$, $c = 1$, $\Omega = 0.5$



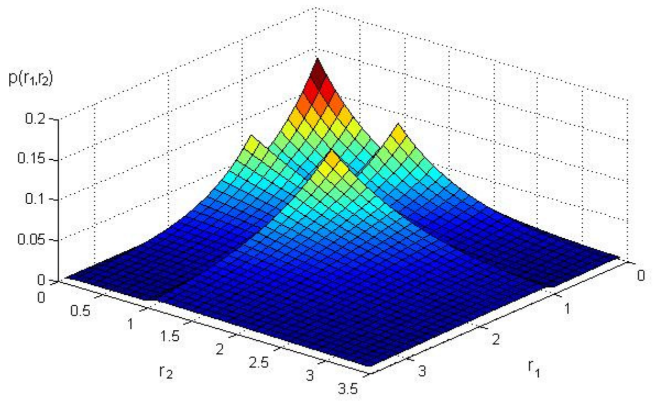
Slika 3.8.5. Združena gustina raspodele verovatnoće na izlazu iz SSC kombinera u dva trenutka vremena u prisustvu gamma fedinga za parametre: $\rho = 0.2$, $r_T = 1$, $c = 1$, $\Omega = 1$



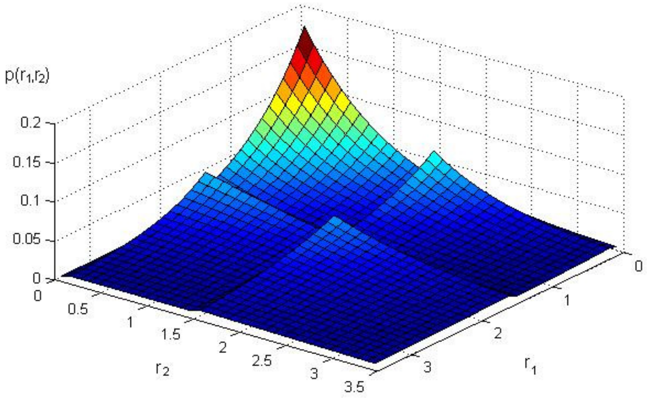
Slika 3.8.6. Združena gustina raspodele verovatnoće na izlazu iz SSC kombinera u dva trenutka vremena u prisustvu gamma fedinga za parametre: $\rho = 0.2$, $r_T = 1$, $c = 1$, $\Omega = 1.5$



Slika 3.8.7. Združena gustina raspodele verovatnoće na izlazu iz SSC kombinera u dva trenutka vremena u prisustvu gamma fedinga za parametre: $\rho = 0.5$, $c = 1$, $\Omega = 1$, $r_T = 1$



Slika 3.8.8. Združena gustina raspodele verovatnoće na izlazu iz SSC kombinera u dva trenutka vremena u prisustvu gamma fedinga za parametre: $\rho = 0.5$, $c = 1$, $\Omega = 1$, $r_T = 2$



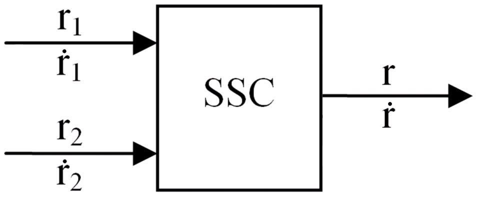
Slika 3.8.9. Združena gustina raspodele verovatnoće na izlazu iz SSC kombinera u dva trenutka vremena u prisustvu gamma fedinga za parametre: $\rho = 0.5$, $c = 1$, $\Omega = 1$, $r_T = 3$

4 Karakteristike drugog reda SSC kombinera

Glavni akcenat u ovoj glavi je dat na razmatranju karakteristika drugog reda SSC kombinera u 2 trenutka vremena, a na osnovu prethodno dobijenih karakteristika prvog reda, kao što je združena gustina raspodele verovatnoće signala na izlazu u dva trenutka vremena. Ovakav slučaj dosad nije razmatran u dostupnoj literaturi, osim u radovima grupe autora među kojima je i autor disertacije [41], [42], [58]-[60]. Rezultati su dobijeni za slučaj da ne postoji korelacija između signala u jednoj grani u dva vremenska trenutka, a da su kao u prethodnom poglavlju međusobno nezavisni signali između grana prijemnika. Za dobijanje karakteristika drugog reda je neophodno uzeti u obzir osim gustina raspodele verovatnoće signala na ulazima u kombiner i gustine raspodele njihovih izvoda.

4.1 Model sistema u jednom trenutku vremena

Razmatra se SSC kombiner sa dva ulaza, kao u modelu predstavljenom na slici 4.1.1. Signali na ulazima su r_1 i r_2, dok su njihovi izvodi $\dot{r}_1$ i $\dot{r}_2$. Signal na izlazu iz kombinera je r, sa izvodom signala $\dot{r}$. Verovatnoća da kombiner prvo razmatra signal na prvoj grani je P_1, a na drugoj je P_2.



Slika 4.1.1. Model SSC kombinera sa dva ulaza u jednom trenutku vremena sa izvodima signala

slučaj $r<r_T$

vrednosti ulaznih signala	vrednosti izvoda izlaznih signala	verovatnoća događaja
$r_1<r_T,\ r_2<r_T$	$\dot r = \dot r_2$	P_1
$r_2<r_T,\ r_1<r_T$	$\dot r = \dot r_1$	P_2

slučaj $r\geq r_T$

vrednosti ulaznih signala	vrednosti izvoda izlaznih signala	verovatnoća događaja
$r_1\geq r_T$	$\dot r = \dot r_1$	P_1
$r_1<r_T,\ r_2\geq r_T$	$\dot r = \dot r_2$	P_1
$r_2\geq r_T$	$\dot r = \dot r_2$	P_2
$r_2<r_T,\ r_1\geq r_T$	$\dot r = \dot r_1$	$P2$

Izraz za združenu gustinu raspodele verovatnoće signala i izvoda signala na izlazu iz kombinera će prvo biti dat za slučaj $r<r_T$. Na osnovu algoritma rada SSC kombinera u ovom slučaju, gustina raspodele verovatnoće je [15]:

$$p_{r\dot r}(r,\dot r)=P_1F_{r_1}(r_T)p_{r_2\dot r_2}(r,\dot r)+P_2F_{r_2}(r_T)p_{r_1\dot r_1}(r,\dot r) \tag{4.1.1}$$

Za slučaj $r\geq r_T$, združena gustinu raspodele verovatnoće signala i izvoda signala na izlazu iz kombinera je:

$$p_{r\dot r}(r,\dot r)=P_1p_{r_1\dot r_1}(r,\dot r)+P_1F_{r_1}(r_T)p_{r_2\dot r_2}(r,\dot r)+P_2p_{r_2\dot r_2}(r,\dot r)+P_2F_{r_2}(r_T)p_{r_1\dot r_1}(r,\dot r) \tag{4.1.2}$$

gde je r_T prag odluke, a kumulativne raspodele verovatnoće su date u trećoj glavi.

U slučaju kada su signal i njegov izvod nekorelisani, njihova združena gustinu raspodele verovatnoće na izlazu je:

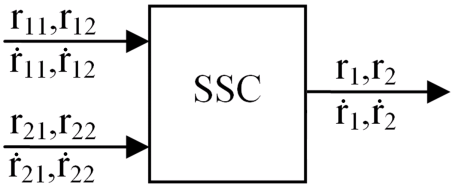
$$p_{r\dot r}(r,\dot r)=P_1F_{r_1}(r_T)p_{r_2}(r)p_{\dot r_2}(\dot r)+P_2F_{r_2}(r_T)p_{r_1}(r)p_{\dot r_1}(\dot r) \tag{4.1.3}$$

Za slučaj $r\geq r_T$, združena gustinu raspodele verovatnoće signala i izvoda signala na izlazu iz kombinera je:

$$p_{r\dot r}(r,\dot r)=P_1p_{r_1}(r)p_{\dot r_1}(\dot r)+P_1F_{r_1}(r_T)p_{r_2}(r)p_{\dot r_2}(\dot r)+P_2p_{r_2}(r)p_{\dot r_2}(\dot r)+P_2F_{r_2}(r_T)p_{r_1}(r)p_{\dot r_1}(\dot r) \tag{4.1.4}$$

4.2 Model sistema u dva trenutka vremena

U ovom poglavlju se razmatra SSC kombiner sa dve grane u dva trenutka vremena. Model sistema je prikazan na slici 4.2.1. Signali na ulazima su r_{11} i r_{21} u prvom trenutku vremena, a r_{12} i r_{22} u drugom trenutku vremena. Signali na izlazu su r_1 i r_2. Izvodi signala na ulazima su $\dot{r}_{11}$ i $\dot{r}_{21}$ u prvom trenutku vremena, a $\dot{r}_{12}$ i $\dot{r}_{22}$ u drugom trenutku vremena. Izvodi signala na izlazu su $\dot{r}_1$ i $\dot{r}_2$. Indeksi za ulazne signale i izvode su: prvi indeks je broj grane, a drugi razmatran vremenski trenutak. Za izlazni signal, indeks predstavlja razmatrani vremenski trenutak. Verovatnoća da kombiner prvo razmatra signal na prvoj grani je P_1, a na drugoj je P_2.



Slika 4.2.1. Model SSC kombinera sa dva ulaza u dva trenutka vremena sa izvodima signala

Za $r_1<r_T$, $r_2<r_T$

U ovom slučaju svi signali su manji od praga r_T, odnosno: $r_{11}<r_T$, $r_{12}<r_T$ $r_{21}<r_T$, $r_{22}<r_T$. Neka kombiner prvo razmatra signal r_{11}. Pošto je $r_{11}<r_T$, onda je $\dot{r}_1=\dot{r}_{21}$, a kako je $r_{22}<r_T$, onda je $\dot{r}_2=\dot{r}_{12}$. Verovatnoća ovog događaja je P_1. Kada kombiner prvo razmatra signal r_{21}, onda važi da je $r_{21}<r_T$, $\dot{r}_1=\dot{r}_{11}$, kao i $r_{21}<r_T$, $\dot{r}_2=\dot{r}_{22}$. Verovatnoća ovog događaja je P_2.

vrednosti ulaznih signala		vrednosti izvoda izlaznih signala	verovatnoća događaja
$r_{11}<r_T$, $r_{21}<r_T$	$r_{22}<r_T$, $r_{12}<r_T$	$\dot{r}_1=\dot{r}_{21}$ $\dot{r}_2=\dot{r}_{12}$	P_1
$r_{21}<r_T$, $r_{11}<r_T$	$r_{12}<r_T$, $r_{22}<r_T$	$\dot{r}_1=\dot{r}_{11}$ $\dot{r}_2=\dot{r}_{22}$	P_2

Za $r_1\geq r_T$, $r_2<r_T$

vrednosti ulaznih signala		vrednosti izvoda izlaznih signala	verovatnoća događaja
$r_{11}\geq r_T$	$r_{12}<r_T$, $r_{22}<r_T$	$\dot{r}_1=\dot{r}_{11}$ $\dot{r}_2=\dot{r}_{22}$	P_1
$r_{11}<r_T$, $r_{21}\geq r_T$	$r_{22}<r_T$, $r_{12}<r_T$	$\dot{r}_1=\dot{r}_{21}$ $\dot{r}_2=\dot{r}_{12}$	P_1
$r_{21}\geq r_T$	$r_{22}<r_T$, $r_{12}<r_T$	$\dot{r}_1=\dot{r}_{21}$ $\dot{r}_2=\dot{r}_{12}$	P_2
$r_{21}<r_T$, $r_{11}\geq r_T$	$r_{12}<r_T$, $r_{22}<r_T$	$\dot{r}_1=\dot{r}_{11}$ $\dot{r}_2=\dot{r}_{22}$	P_2

Za $r_1<r_T$, $r_2\geq r_T$

vrednosti ulaznih signala vrednosti izvoda izlaznih signala verovatnoća događaja

$r_{11}<r_T$, $r_{21}<r_T$	$r_{22}\geq r_T$	$\dot r_1 = \dot r_{21}$ $\dot r_2 = \dot r_{22}$	P_1
$r_{11}<r_T$, $r_{21}<r_T$	$r_{22}<r_T$, $r_{12}\geq r_T$	$\dot r_1 = \dot r_{21}$ $\dot r_2 = \dot r_{12}$	P_1
$r_{21}<r_T$, $r_{11}<r_T$	$r_{12}\geq r_T$	$\dot r_1 = \dot r_{11}$ $\dot r_2 = \dot r_{12}$	P_2
$r_{21}<r_T$, $r_{11}<r_T$	$r_{12}<r_T$, $r_{22}\geq r_T$	$\dot r_1 = \dot r_{11}$ $\dot r_2 = \dot r_{22}$	P_2

Za $r_1\geq r_T$, $r_2\geq r_T$

vrednosti ulaznih signala		vrednosti izvoda izlaznih signala	verovatnoća događaja
$r_{11}\geq r_T$, $r_{12}\geq r_T$		$\dot r_1 = \dot r_{11}$ $\dot r_2 = \dot r_{12}$	P_1
$r_{11}\geq r_T$	$r_{12}<r_T$, $r_{22}\geq r_T$	$\dot r_1 = \dot r_{11}$ $\dot r_2 = \dot r_{22}$	P_1
$r_{11}<r_T$, $r_{21}\geq r_T$	$r_{22}\geq r_T$	$\dot r_1 = \dot r_{21}$ $\dot r_2 = \dot r_{22}$	P_1
$r_{11}<r_T$, $r_{21}\geq r_T$	$r_{22}<r_T$, $r_{12}<r_T$	$\dot r_1 = \dot r_{21}$ $\dot r_2 = \dot r_{12}$	P_1
$r_{21}\geq r_T$	$r_{22}\geq r_T$	$\dot r_1 = \dot r_{21}$ $\dot r_2 = \dot r_{22}$	P_2
$r_{21}\geq r_T$	$r_{22}<r_T$, $r_{12}\geq r_T$	$\dot r_1 = \dot r_{21}$ $\dot r_2 = \dot r_{12}$	P_2
$r_{21}<r_T$, $r_{11}\geq r_T$	$r_{12}\geq r_T$	$\dot r_1 = \dot r_{11}$ $\dot r_2 = \dot r_{12}$	P_2
$r_{21}<r_T$, $r_{11}\geq r_T$	$r_{12}<r_T$, $r_{22}\geq r_T$	$\dot r_1 = \dot r_{11}$ $\dot r_2 = \dot r_{22}$	P_2

Združena gustina raspodele verovatnoće signala i izvoda signala $p_{r_1 r_2 \dot r_1 \dot r_2}(r_1, r_2, \dot r_1, \dot r_2)$ na izlazu iz SSC kombinera u 2 trenutka vremena se može na osnovu (3.2.1-4) predstaviti u obliku:

Za $r_1<r_T$, $r_2<r_T$

$$p_{r_1 r_2 \dot r_1 \dot r_2}(r_1, r_2, \dot r_1, \dot r_2) = P_1 \int_0^{r_T} dr_{11} \int_0^{r_T} dr_{22}\, p_{r_{11} r_{22} r_{21} r_{12} \dot r_{21} \dot r_{12}}(r_{11}, r_{22}, r_1, r_2, \dot r_1, \dot r_2) +$$

$$+ P_2 \int_0^{r_T} dr_{21} \int_0^{r_T} dr_{12}\, p_{r_{21} r_{12} r_{11} r_{22} \dot r_{11} \dot r_{22}}(r_{21}, r_{12}, r_1, r_2, \dot r_1, \dot r_2) \tag{4.2.1}$$

Za $r_1\geq r_T$, $r_2<r_T$

$$p_{r_1 r_2 \dot r_1 \dot r_2}(r_1, r_2, \dot r_1, \dot r_2) = P_1 \int_0^{r_T} dr_{12}\, p_{r_{12} r_{11} r_{22} \dot r_{11} \dot r_{22}}(r_{12}, r_1, r_2, \dot r_1, \dot r_2) +$$

$$+ P_1 \int_0^{r_T} dr_{11} \int_0^{r_T} dr_{22}\, p_{r_{11} r_{22} r_{21} r_{12} \dot r_{21} \dot r_{12}}(r_{11}, r_{22}, r_1, r_2, \dot r_1, \dot r_2) +$$

$$+ P_2 \int_0^{r_T} dr_{22}\, p_{r_{22} r_{21} r_{12} \dot r_{21} \dot r_{12}}(r_{22}, r_1, r_2, \dot r_1, \dot r_2) + P_2 \int_0^{r_T} dr_{21} \int_0^{r_T} dr_{12}\, p_{r_{21} r_{12} r_{11} r_{22} \dot r_{11} \dot r_{22}}(r_{21}, r_{12}, r_1, r, \dot r_1, \dot r_2) \tag{4.2.2}$$

Za $r_1<r_T$, $r_2\geq r_T$

$$p_{r_1r_2\dot{r}_1\dot{r}_2}(r_1,r_2,\dot{r}_1,\dot{r}_2)=P_1\int_0^{r_T}dr_{11}\,p_{r_{11}r_{21}r_{22}\dot{r}_{21}\dot{r}_{22}}(r_{11},r_1,r_2,\dot{r}_1,\dot{r}_2)+$$

$$+P_1\int_0^{r_T}dr_{11}\int_0^{r_T}dr_{22}\,p_{r_{11}r_{22}r_{21}r_{12}\dot{r}_{21}\dot{r}_{12}}(r_{11},r_{22},r_1,r_2,\dot{r}_1,\dot{r}_2)+$$

$$+P_2\int_0^{r_T}dr_{21}\,p_{r_{21}r_{11}r_{12}\dot{r}_{11}\dot{r}_{12}}(r_{21},r_1,r_2,\dot{r}_1,\dot{r}_2)+P_2\int_0^{r_T}dr_{21}\int_0^{r_T}dr_{12}\,p_{r_{21}r_{12}r_{11}r_{22}\dot{r}_{11}\dot{r}_{22}}(r_{21},r_{12},r_1,r,\dot{r}_1,\dot{r}_2) \qquad (4.2.3)$$

Za $r_1\geq r_T$, $r_2\geq r_T$

$$p_{r_1r_2\dot{r}_1\dot{r}_2}(r_1,r_2,\dot{r}_1,\dot{r}_2)=P_1p_{r_{11}r_{12}\dot{r}_{11}\dot{r}_{12}}(r_1,r_2,\dot{r}_1,\dot{r}_2)+P_1\int_0^{r_T}dr_{12}\,p_{r_{12}r_{11}r_{22}\dot{r}_{11}\dot{r}_{22}}(r_{12},r_1,r_2,\dot{r}_1,\dot{r}_2)+$$

$$+P_1\int_0^{r_T}dr_{11}\,p_{r_{11}r_{21}r_{22}\dot{r}_{21}\dot{r}_{22}}(r_{11},r_1,r_2,\dot{r}_1,\dot{r}_2)+P_1\int_0^{r_T}dr_{11}\int_0^{r_T}dr_{22}\,p_{r_{11}r_{22}r_{21}r_{12}\dot{r}_{21}\dot{r}_{12}}(r_{11},r_{22},r_1,r_2,\dot{r}_1,\dot{r}_2)+$$

$$+P_2p_{r_{21}r_{22}\dot{r}_{21}\dot{r}_{22}}(r_1,r_2,\dot{r}_1,\dot{r}_2)+P_2\int_0^{r_T}dr_{22}\,p_{r_{22}r_{21}r_{12}\dot{r}_{21}\dot{r}_{12}}(r_{22},r_1,r_2,\dot{r}_1,\dot{r}_2)+$$

$$+P_2\int_0^{r_T}dr_{21}\,p_{r_{21}r_{11}r_{12}\dot{r}_{11}\dot{r}_{12}}(r_{21},r_1,r_2,\dot{r}_1,\dot{r}_2)+P_2\int_0^{r_T}dr_{21}\int_0^{r_T}dr_{12}\,p_{r_{21}r_{12}r_{11}r_{22}\dot{r}_{11}\dot{r}_{22}}(r_{21},r_{12},r_1,r,\dot{r}_1,\dot{r}_2) \qquad (4.2.4)$$

Za slučaj kada su signali u granama prijemnika u jednom vremenskom trenutku, kao i signali u jednoj grani u dva vremenska trenutka međusobno nekorelisani, marginalna združena gustina raspodele verovatnoće signala i njegovog izvoda $p_{r_i\dot{r}_i}(r_i,\dot{r}_i)$ se može dobiti upotrebom združene gustine raspodele verovatnoće signala i izvoda $p_{r_1r_2\dot{r}_1\dot{r}_2}(r_1,r_2,\dot{r}_1,\dot{r}_2)$ [4], [61]:

$$p_{r_i\dot{r}_i}(r_i,\dot{r}_i)=\int_{-\infty}^{\infty}dr_j\int_0^{\infty}d\dot{r}_j\,p_{r_1r_2\dot{r}_1\dot{r}_2}(r_i,r_j,\dot{r}_i,\dot{r}_j),\quad i,j=1,2,\quad i\neq j \qquad (4.2.5)$$

$$p_{r_i\dot{r}_i}(r_i,\dot{r}_i)=\int_0^{r_T}dr_j\int_{-\infty}^{\infty}d\dot{r}_j\,p_{r_1r_2\dot{r}_1\dot{r}_2}(r_i,r_j,\dot{r}_i,\dot{r}_j)+\int_{r_T}^{\infty}dr_j\int_{-\infty}^{\infty}d\dot{r}_j\,p_{r_1r_2\dot{r}_1\dot{r}_2}(r_i,r_j,\dot{r}_i,\dot{r}_j),\ i,j=1,2,\quad i\neq j \qquad (4.2.6)$$

Na osnovu (4.2.6), i primenom izraza (3.2.5-3.2.8) za različite oblasti vrednosti signala na ulazima kombinera, dobijaju se združene gustine raspodele verovatnoće signala i izvoda $p_{r_1\dot{r}_1}(r_1,\dot{r}_1)$ i $p_{r_2\dot{r}_2}(r_2,\dot{r}_2)$.

Za $r_1<r_T$, $p_{r_1\dot{r}_1}(r_1,\dot{r}_1)$ je:

$$\begin{aligned}
p_{r_1\dot{r}_1}(r_1,\dot{r}_1) = {} & P_1 p_{r_{21}\dot{r}_{21}}(r_1,\dot{r}_1)\int_0^{r_T} dr_{11} p_{r_{11}}(r_{11})\int_0^{r_T} dr_{22} p_{r_{22}}(r_{22})\int_0^{r_T} dr_2 \int_{-\infty}^{\infty} d\dot{r}_2 p_{r_{12}\dot{r}_{12}}(r_2,\dot{r}_2)+\\
& + P_2 p_{r_{11}\dot{r}_{11}}(r_1,\dot{r}_1)\int_0^{r_T} dr_{21} p_{r_{21}}(r_{21})\int_0^{r_T} dr_{12} p_{r_{12}}(r_{12})\int_0^{r_T} dr_2 \int_{-\infty}^{\infty} d\dot{r}_2 p_{r_{22}\dot{r}_{22}}(r_2,\dot{r}_2)+\\
& + P_1 p_{r_{21}\dot{r}_{21}}(r_1,\dot{r}_1)\int_0^{r_T} dr_{11} p_{r_{11}}(r_{11})\int_{r_T}^{\infty} dr_2 \int_{-\infty}^{\infty} d\dot{r}_2 p_{r_{22}\dot{r}_{22}}(r_2,\dot{r}_2)+\\
& + P_1 p_{r_{21}\dot{r}_{21}}(r_1,\dot{r}_1)\int_0^{r_T} dr_{11} p_{r_{11}}(r_{11})\int_0^{r_T} dr_{22} p_{r_{22}}(r_{22})\int_{r_T}^{\infty} dr_2 \int_{-\infty}^{\infty} d\dot{r}_2 p_{r_{12}\dot{r}_{12}}(r_2,\dot{r}_2)+\\
& + P_2 p_{r_{11}\dot{r}_{11}}(r_1,\dot{r}_1)\int_0^{r_T} dr_{21} p_{r_{21}}(r_{21})\int_{r_T}^{\infty} dr_2 \int_{-\infty}^{\infty} d\dot{r}_2 p_{r_{12}\dot{r}_{12}}(r_2,\dot{r}_2)+\\
& + P_2 p_{r_{11}\dot{r}_{11}}(r_1,\dot{r}_1)\int_0^{r_T} dr_{21} p_{r_{21}}(r_{21})\int_0^{r_T} dr_{12} p_{r_{12}}(r_{12})\int_{r_T}^{\infty} dr_2 \int_{-\infty}^{\infty} d\dot{r}_2 p_{r_{22}\dot{r}_{22}}(r_2,\dot{r}_2)
\end{aligned} \tag{4.2.7}$$

Za $r_1 \geq r_T$, $p_{r_1\dot{r}_1}(r_1,\dot{r}_1)$ je:

$$\begin{aligned}
p_{r_1\dot{r}_1}(r_1,\dot{r}_1) = {} & P_1 p_{r_{11}\dot{r}_{11}}(r_1,\dot{r}_1)\int_0^{r_T} dr_{12} p_{r_{12}}(r_{12})\int_0^{r_T} dr_2 \int_{-\infty}^{\infty} d\dot{r}_2 p_{r_{22}\dot{r}_{22}}(r_2,\dot{r}_2)+\\
& + P_1 p_{r_{21}\dot{r}_{21}}(r_1,\dot{r}_1)\int_0^{r_T} dr_{11} p_{r_{11}}(r_{11})\int_0^{r_T} dr_{22} p_{r_{22}}(r_{22})\int_0^{r_T} dr_2 \int_{-\infty}^{\infty} d\dot{r}_2 p_{r_{12}\dot{r}_{12}}(r_2,\dot{r}_2)+\\
& + P_2 p_{r_{21}\dot{r}_{21}}(r_1,\dot{r}_1)\int_0^{r_T} dr_{22} p_{r_{22}}(r_{22})\int_0^{r_T} dr_2 \int_{-\infty}^{\infty} d\dot{r}_2 p_{r_{12}\dot{r}_{12}}(r_2,\dot{r}_2)+\\
& + P_2 p_{r_{11}\dot{r}_{11}}(r_1,\dot{r}_1)\int_0^{r_T} dr_{21} p_{r_{21}}(r_{21})\int_0^{r_T} dr_{12} p_{r_{12}}(r_{12})\int_0^{r_T} dr_2 \int_{-\infty}^{\infty} d\dot{r}_2 p_{r_{22}\dot{r}_{22}}(r_2,\dot{r}_2)+\\
& + P_1 p_{r_{11}\dot{r}_{11}}(r_1,\dot{r}_1)\int_{r_T}^{\infty} dr_2 \int_{-\infty}^{\infty} d\dot{r}_2 p_{r_{12}\dot{r}_{12}}(r_2,\dot{r}_2)+\\
& + P_1 p_{r_{11}\dot{r}_{11}}(r_1,\dot{r}_1)\int_0^{r_T} dr_{12} p_{r_{12}}(r_{12})\int_{r_T}^{\infty} dr_2 \int_{-\infty}^{\infty} d\dot{r}_2 p_{r_{22}\dot{r}_{22}}(r_2,\dot{r}_2)+\\
& + P_1 p_{r_{21}\dot{r}_{21}}(r_1,\dot{r}_1)\int_0^{r_T} dr_{11} p_{r_{11}}(r_{11})\int_{r_T}^{\infty} dr_2 \int_{-\infty}^{\infty} d\dot{r}_2 p_{r_{22}\dot{r}_{22}}(r_2,\dot{r}_2)+\\
& + P_1 p_{r_{21}\dot{r}_{21}}(r_1,\dot{r}_1)\int_0^{r_T} dr_{11} p_{r_{11}}(r_{11})\int_0^{r_T} dr_{22} p_{r_{22}}(r_{22})\int_{r_T}^{\infty} dr_2 \int_{-\infty}^{\infty} d\dot{r}_2 p_{r_{12}\dot{r}_{12}}(r_2,\dot{r}_2)+
\end{aligned}$$

$$+P_2 p_{r_{21}\dot{r}_{21}}(r_1,\dot{r}_1)\int_{r_T}^{\infty} dr_2 \int_{-\infty}^{\infty} d\dot{r}_2\, p_{r_{22}\dot{r}_{22}}(r_2,\dot{r}_2)+$$

$$+P_2 p_{r_{21}\dot{r}_{21}}(r_1,\dot{r}_1)\int_{0}^{r_T} dr_{22}\, p_{r_{22}}(r_{22})\int_{r_T}^{\infty} dr_2 \int_{-\infty}^{\infty} d\dot{r}_2\, p_{r_{12}\dot{r}_{12}}(r_2,\dot{r}_2)+$$

$$+P_2 p_{r_{11}\dot{r}_{11}}(r_1,\dot{r}_1)\int_{0}^{r_T} dr_{21}\, p_{r_{21}}(r_{21})\int_{r_T}^{\infty} dr_2 \int_{-\infty}^{\infty} d\dot{r}_2\, p_{r_{12}\dot{r}_{12}}(r_2,\dot{r}_2)+$$

$$+P_2 p_{r_{11}\dot{r}_{11}}(r_1,\dot{r}_1)\int_{0}^{r_T} dr_{21}\, p_{r_{21}}(r_{21})\int_{0}^{r_T} dr_{12}\, p_{r_{12}}(r_{12})\int_{r_T}^{\infty} dr_2 \int_{-\infty}^{\infty} d\dot{r}_2\, p_{r_{22}\dot{r}_{22}}(r_2,\dot{r}_2) \qquad (4.2.8)$$

Za $r_2<r_T$, $p_{r_2\dot{r}_2}(r_2,\dot{r}_2)$ je:

$$p_{r_2\dot{r}_2}(r_2,\dot{r}_2)=P_1 p_{r_{12}\dot{r}_{12}}(r_2,\dot{r}_2)\int_{0}^{r_T} dr_{11}\, p_{r_{11}}(r_{11})\int_{0}^{r_T} dr_{22}\, p_{r_{22}}(r_{22})\int_{0}^{r_T} dr_1 \int_{-\infty}^{\infty} d\dot{r}_1\, p_{r_{21}\dot{r}_{21}}(r_1,\dot{r}_1)+$$

$$+P_2 p_{r_{22}\dot{r}_{22}}(r_2,\dot{r}_2)\int_{0}^{r_T} dr_{21}\, p_{r_{21}}(r_{21})\int_{0}^{r_T} dr_{12}\, p_{r_{12}}(r_{12})\int_{0}^{r_T} dr_1 \int_{-\infty}^{\infty} d\dot{r}_1\, p_{r_{11}\dot{r}_{11}}(r_1,\dot{r}_1)+$$

$$+P_1 p_{r_{22}\dot{r}_{22}}(r_2,\dot{r}_2)\int_{0}^{r_T} dr_{12}\, p_{r_{12}}(r_{12})\int_{r_T}^{\infty} dr_1 \int_{-\infty}^{\infty} d\dot{r}_1\, p_{r_{11}\dot{r}_{11}}(r_1,\dot{r}_1)+$$

$$+P_1 p_{r_{12}\dot{r}_{12}}(r_2,\dot{r}_2)\int_{0}^{r_T} dr_{11}\, p_{r_{11}}(r_{11})\int_{0}^{r_T} dr_{22}\, p_{r_{22}}(r_{22})\int_{r_T}^{\infty} dr_1 \int_{-\infty}^{\infty} d\dot{r}_1\, p_{r_{21}\dot{r}_{21}}(r_1,\dot{r}_1)+$$

$$+P_2 p_{r_{12}\dot{r}_{12}}(r_2,\dot{r}_2)\int_{0}^{r_T} dr_{22}\, p_{r_{22}}(r_{22})\int_{r_T}^{\infty} dr_1 \int_{-\infty}^{\infty} d\dot{r}_1\, p_{r_{21}\dot{r}_{21}}(r_1,\dot{r}_1)+$$

$$+P_2 p_{r_{22}\dot{r}_{22}}(r_2,\dot{r}_2)\int_{0}^{r_T} dr_{21}\, p_{r_{21}}(r_{21})\int_{0}^{r_T} dr_{12}\, p_{r_{12}}(r_{12})\int_{r_T}^{\infty} dr_1 \int_{-\infty}^{\infty} d\dot{r}_1\, p_{r_{11}\dot{r}_{11}}(r_1,\dot{r}_1) \qquad (4.2.9)$$

Za $r_2 \geq r_T$, $p_{r_2\dot{r}_2}(r_2,\dot{r}_2)$ je:

$$p_{r_2\dot{r}_2}(r_2,\dot{r}_2)=P_1 p_{r_{22}\dot{r}_{22}}(r_2,\dot{r}_2)\int_{0}^{r_T} dr_{11}\, p_{r_{11}}(r_{11})\int_{0}^{r_T} dr_1 \int_{-\infty}^{\infty} d\dot{r}_1\, p_{r_{21}\dot{r}_{21}}(r_1,\dot{r}_1)+$$

$$+P_1 p_{r_{12}\dot{r}_{12}}(r_2,\dot{r}_2)\int_{0}^{r_T} dr_{11}\, p_{r_{11}}(r_{11})\int_{0}^{r_T} dr_{22}\, p_{r_{22}}(r_{22})\int_{0}^{r_T} dr_1 \int_{-\infty}^{\infty} d\dot{r}_1\, p_{r_{21}\dot{r}_{21}}(r_1,\dot{r}_1)+$$

$$+P_2 p_{r_{12}\dot{r}_{12}}(r_2,\dot{r}_2)\int_{0}^{r_T} dr_{21}\, p_{r_{21}}(r_{21})\int_{0}^{r_T} dr_1 \int_{-\infty}^{\infty} d\dot{r}_1\, p_{r_{11}\dot{r}_{11}}(r_1,\dot{r}_1)+$$

$$+P_2 p_{r_{22}\dot{r}_{22}}(r_2,\dot{r}_2)\int_{0}^{r_T} dr_{21}\, p_{r_{21}}(r_{21})\int_{0}^{r_T} dr_{12}\, p_{r_{12}}(r_{12})\int_{0}^{r_T} dr_1 \int_{-\infty}^{\infty} d\dot{r}_1\, p_{r_{11}\dot{r}_{11}}(r_1,\dot{r}_1)+$$

$$+P_1 p_{r_{12}\dot{r}_{12}}(r_2,\dot{r}_2)\int_{r_T}^{\infty} dr_1 \int_{-\infty}^{\infty} d\dot{r}_1 p_{r_{11}\dot{r}_{11}}(r_1,\dot{r}_1)+$$

$$+P_1 p_{r_{22}\dot{r}_{22}}(r_2,\dot{r}_2)\int_{0}^{r_T} dr_{12} p_{r_{12}}(r_{12})\int_{r_T}^{\infty} dr_1 \int_{-\infty}^{\infty} d\dot{r}_1 p_{r_{11}\dot{r}_{11}}(r_1,\dot{r}_1)+$$

$$+P_1 p_{r_{22}\dot{r}_{22}}(r_2,\dot{r}_2)\int_{0}^{r_T} dr_{11} p_{r_{11}}(r_{11})\int_{r_T}^{\infty} dr_1 \int_{-\infty}^{\infty} d\dot{r}_1 p_{r_{21}\dot{r}_{21}}(r_1,\dot{r}_1)+$$

$$+P_1 p_{r_{12}\dot{r}_{12}}(r_2,\dot{r}_2)\int_{0}^{r_T} dr_{11} p_{r_{11}}(r_{11})\int_{0}^{r_T} dr_{22} p_{r_{22}}(r_{22})\int_{r_T}^{\infty} dr_1 \int_{-\infty}^{\infty} d\dot{r}_1 p_{r_{21}\dot{r}_{21}}(r_1,\dot{r}_1)+$$

$$+P_2 p_{r_{22}\dot{r}_{22}}(r_2,\dot{r}_2)\int_{r_T}^{\infty} dr_1 \int_{-\infty}^{\infty} d\dot{r}_1 p_{r_{21}\dot{r}_{21}}(r_1,\dot{r}_1)+$$

$$+P_2 p_{r_{12}\dot{r}_{12}}(r_2,\dot{r}_2)\int_{0}^{r_T} dr_{22} p_{r_{22}}(r_{22})\int_{r_T}^{\infty} dr_1 \int_{-\infty}^{\infty} d\dot{r}_1 p_{r_{21}\dot{r}_{21}}(r_1,\dot{r}_1)+$$

$$+P_2 p_{r_{12}\dot{r}_{12}}(r_2,\dot{r}_2)\int_{0}^{r_T} dr_{21} p_{r_{21}}(r_{21})\int_{r_T}^{\infty} dr_1 \int_{-\infty}^{\infty} d\dot{r}_1 p_{r_{11}\dot{r}_{11}}(r_1,\dot{r}_1)+$$

$$+P_2 p_{r_{22}\dot{r}_{22}}(r_2,\dot{r}_2)\int_{0}^{r_T} dr_{21} p_{r_{21}}(r_{21})\int_{0}^{r_T} dr_{12} p_{r_{12}}(r_{12})\int_{r_T}^{\infty} dr_1 \int_{-\infty}^{\infty} d\dot{r}_1 p_{r_{11}\dot{r}_{11}}(r_1,\dot{r}_1) \qquad (4.2.10)$$

Nakon određenih matematičkih transformacija, dobijaju se konačni izrazi za združene gustine raspodele verovatnoće signala i izvoda na izlazu iz SSC kombinera u 2 trenutka vremena. *F_i( )*, *p_i(,)* i *p_i( )* označavaju statističke parametre signala i izvoda sa *i*-te ulazne grane kombinera, pri čemu važi da su raspodele u jednoj grani kombinera iste u oba trenutka vremena.

Za $r_1 < r_T$, $p_{r_1\dot{r}_1}(r_1,\dot{r}_1)$ je:

$$p_{r_1\dot{r}_1}(r_1,\dot{r}_1) = P_1 p_2(r_1,\dot{r}_1)F_1(r_T)F_2(r_T) + P_2 p_1(r_1,\dot{r}_1)F_1(r_T)F_2(r_T)+$$

$$+P_1 p_2(r_1,\dot{r}_1)F_1(r_T)\int_{r_T}^{\infty} dr_2 \int_{-\infty}^{\infty} d\dot{r}_2 p_2(r_2,\dot{r}_2)+$$

$$+P_2 p_1(r_1,\dot{r}_1)F_2(r_T)\int_{r_T}^{\infty} dr_2 \int_{-\infty}^{\infty} d\dot{r}_2 p_1(r_2,\dot{r}_2) \qquad (4.2.11)$$

Za $r_1 \geq r_T$, $p_{r_1\dot{r}_1}(r_1,\dot{r}_1)$ je:

$$p_{r_1\dot{r}_1}(r_1,\dot{r}_1) = P_1 p_1(r_1,\dot{r}_1)F_1(r_T) + P_1 p_2(r_1,\dot{r}_1)F_1(r_T)F_2(r_T)+$$

$$+P_2 p_2(r_1,\dot{r}_1)F_2(r_T) + P_2 p_1(r_1,\dot{r}_1)F_1(r_T)F_2(r_T)+$$

$$+P_1 p_1(r_1,\dot{r}_1)\int_{r_T}^{\infty} dr_2 \int_{-\infty}^{\infty} d\dot{r}_2 p_1(r_2,\dot{r}_2)+P_1 p_2(r_1,\dot{r}_1)F_1(r_T)\int_{r_T}^{\infty} dr_2 \int_{-\infty}^{\infty} d\dot{r}_2 p_2(r_2,\dot{r}_2)+$$

$$+P_2 p_2(r_1,\dot{r}_1)\int_{r_T}^{\infty} dr_2 \int_{-\infty}^{\infty} d\dot{r}_2 p_2(r_2,\dot{r}_2)+P_2 p_1(r_1,\dot{r}_1)F_2(r_T)\int_{r_T}^{\infty} dr_2 \int_{-\infty}^{\infty} d\dot{r}_2 p_1(r_2,\dot{r}_2) \qquad (4.2.12)$$

Za $r_2<r_T$, $p_{r_2\dot{r}_2}(r_2,\dot{r}_2)$ je:

$$p_{r_2\dot{r}_2}(r_2,\dot{r}_2)=P_1 p_1(r_2,\dot{r}_2)F_1(r_T)F_2(r_T)+P_2 p_2(r_2,\dot{r}_2)F_1(r_T)F_2(r_T)+$$

$$+P_1 p_2(r_2,\dot{r}_2)F_1(r_T)\int_{r_T}^{\infty} dr_1 \int_{-\infty}^{\infty} d\dot{r}_1 p_1(r_1,\dot{r}_1)+P_2 p_1(r_2,\dot{r}_2)F_2(r_T)\int_{r_T}^{\infty} dr_1 \int_{-\infty}^{\infty} d\dot{r}_1 p_2(r_1,\dot{r}_1) \qquad (4.2.13)$$

Za $r_2 \geq r_T$, $p_{r_2\dot{r}_2}(r_2,\dot{r}_2)$ je:

$$p_{r_2\dot{r}_2}(r_2,\dot{r}_2)=P_1 p_1(r_2,\dot{r}_2)F_1(r_T)F_2(r_T)+P_1 p_2(r_2,\dot{r}_2)F_1(r_T)+$$

$$+P_2 p_1(r_2,\dot{r}_2)F_2(r_T)+P_2 p_2(r_2,\dot{r}_2)F_1(r_T)F_2(r_T)+$$

$$+P_1 p_1(r_2,\dot{r}_2)\int_{r_T}^{\infty} dr_1 \int_{-\infty}^{\infty} d\dot{r}_1 p_1(r_1,\dot{r}_1)+P_1 p_2(r_2,\dot{r}_2)F_1(r_T)\int_{r_T}^{\infty} dr_1 \int_{-\infty}^{\infty} d\dot{r}_1 p_1(r_1,\dot{r}_1)+$$

$$+P_2 p_1(r_2,\dot{r}_2)F_2(r_T)\int_{r_T}^{\infty} dr_1 \int_{-\infty}^{\infty} d\dot{r}_1 p_2(r_1,\dot{r}_1)+P_2 p_2(r_2,\dot{r}_2)\int_{r_T}^{\infty} dr_1 \int_{-\infty}^{\infty} d\dot{r}_1 p_2(r_1,\dot{r}_1) \qquad (4.2.14)$$

Za slučaj da su signal i njegov izvod medjusobno nezavisni procesi, gustine raspodele verovatnoće izvoda se mogu dobiti integraljenjem po celom opsegu raspodele signala:

$$p_{\dot{r}_i}(\dot{r}_i)=\int_{0}^{\infty} d\dot{r}_i p_{r_i\dot{r}_i}(r_i,\dot{r}_i)=\int_{0}^{r_T} d\dot{r}_i p_{r_i\dot{r}_i}(r_i,\dot{r}_i)+\int_{r_T}^{\infty} d\dot{r}_i p_{r_i\dot{r}_i}(r_i,\dot{r}_i), \quad i=1,2 \qquad (4.2.15)$$

Zamenom (4.2.11-14) u 4.2.15, dobijaju se izrazi za $p_{\dot{r}_1}(\dot{r}_1)$ i $p_{\dot{r}_2}(\dot{r}_2)$:

$$p_{\dot{r}_1}(\dot{r}_1)=P_1(1-F_1(r_T))p_1(\dot{r}_1)+P_2F_2(r_T)p_1(\dot{r}_1)+$$

$$+P_1F_1(r_T)p_2(\dot{r}_1)+P_2(1-F_2(r_T))p_2(\dot{r}_1) \qquad (4.2.16)$$

$$p_{\dot{r}_2}(\dot{r}_2)=P_1F_1(r_T)F_2(r_T)p_1(\dot{r}_2)+P_1(1-F_1(r_T))(1-F_1(r_T))p_1(\dot{r}_2)+$$

$$+P_2F_2(r_T)(1-F_2(r_T))p_1(\dot{r}_2)+P_2(1-F_1(r_T))F_2(r_T)p_1(\dot{r}_2)+$$

$$+P_1F_1(r_T)(1-F_1(r_T))p_2(\dot{r}_2)+P_1F_1(r_T)(1-F_2(r_T))p_2(\dot{r}_2)+$$

$$P_2F_1(r_T)F_2(r_T)p_2(\dot{r}_2)+P_2(1-F_2(r_T))(1-F_2(r_T))p^2(\dot{r}_2) \qquad (4.2.17)$$

4.3 Gustina raspodele verovatnoće izvoda signala na izlazu SSC kombinera u dva trenutka vremena u prisustvu Rayleigh-jevog fedinga

Gustine raspodele verovatnoće izvoda signala na ulazu u kombiner $\dot{r}_{i,j}$ u prisustvu Rayleigh-jevog fedinga imaju normalnu raspodelu sa nultom srednjom vrednošću [16], [19]:

$$p_{\dot{r}_i}(\dot{r}_{i,j}) = \frac{1}{\sqrt{2\pi}\dot{\sigma}_i} e^{-\frac{\dot{r}_{i,j}{}^2}{2\dot{\sigma}_i{}^2}} \quad ,-\infty < \dot{r}_{i,j} < \infty \tag{4.3.1}$$

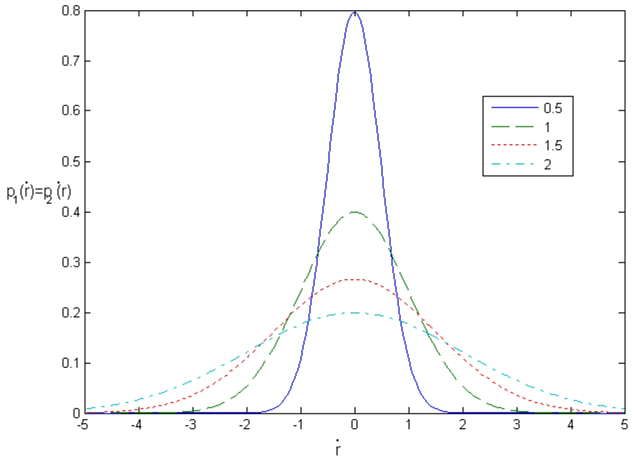
gde su *i=1,2 j=1,2* i $\dot{\sigma}_i{}^2 = 2\sigma^2\pi^2 f_m{}^2$ je varijansa, dok je f_m maksimalni Doppler-ov frekventni pomeraj.

Gustine raspodele verovatnoće izvoda signala $\dot{r}_1$ i $\dot{r}_2$ na izlazu iz SSC kombinera u dva trenutka vremena u prisustvu Rayleigh-jevog fedinga se dobija kada se u prethodno dobijene opšte izraze CDF signala i PDF njegovog izvoda zamene u (3.3.2) i (4.3.1)

$$\begin{aligned} p_{\dot{r}_1}(\dot{r}_1) = {} & P_1 e^{-\frac{r_T}{2\sigma_1{}^2}} \frac{1}{\sqrt{2\pi}\dot{\sigma}_1} e^{-\frac{\dot{r}_1{}^2}{2\dot{\sigma}_1{}^2}} + P_2\left(1-e^{-\frac{r_T}{2\sigma_2{}^2}}\right)\frac{1}{\sqrt{2\pi}\dot{\sigma}_1} e^{-\frac{\dot{r}_1{}^2}{2\dot{\sigma}_1{}^2}} + \\ & + P_1\left(1-e^{-\frac{r_T}{2\sigma_1{}^2}}\right)\frac{1}{\sqrt{2\pi}\dot{\sigma}_2} e^{-\frac{\dot{r}_1{}^2}{2\dot{\sigma}_2{}^2}} + P_2 e^{-\frac{r_T}{2\sigma_2{}^2}} \frac{1}{\sqrt{2\pi}\dot{\sigma}_2} e^{-\frac{\dot{r}_1{}^2}{2\dot{\sigma}_2{}^2}} \end{aligned} \tag{4.3.2}$$

$$\begin{aligned} p_{\dot{r}_2}(\dot{r}_2) = {} & P_1\left(1-e^{-\frac{r_T}{2\sigma_1{}^2}}\right)\left(1-e^{-\frac{r_T}{2\sigma_2{}^2}}\right)\frac{1}{\sqrt{2\pi}\dot{\sigma}_1} e^{-\frac{\dot{r}_2{}^2}{2\dot{\sigma}_1{}^2}} + P_1 e^{-\frac{r_T}{2\sigma_1{}^2}} e^{-\frac{r_T}{2\sigma_1{}^2}} \frac{1}{\sqrt{2\pi}\dot{\sigma}_1} e^{-\frac{\dot{r}_2{}^2}{2\dot{\sigma}_1{}^2}} + \\ & + P_2\left(1-e^{-\frac{r_T}{2\sigma_2{}^2}}\right) e^{-\frac{r_T}{2\sigma_2{}^2}} \frac{1}{\sqrt{2\pi}\dot{\sigma}_1} e^{-\frac{\dot{r}_2{}^2}{2\dot{\sigma}_1{}^2}} + P_2 e^{-\frac{r_T}{2\sigma_1{}^2}}\left(1-e^{-\frac{r_T}{2\sigma_2{}^2}}\right)\frac{1}{\sqrt{2\pi}\dot{\sigma}_1} e^{-\frac{\dot{r}_2{}^2}{2\dot{\sigma}_1{}^2}} + \\ & + P_1\left(1-e^{-\frac{r_T}{2\sigma_1{}^2}}\right) e^{-\frac{r_T}{2\sigma_1{}^2}} \frac{1}{\sqrt{2\pi}\dot{\sigma}_2} e^{-\frac{\dot{r}_2{}^2}{2\dot{\sigma}_2{}^2}} + P_1\left(1-e^{-\frac{r_T}{2\sigma_1{}^2}}\right) e^{-\frac{r_T}{2\sigma_2{}^2}} \frac{1}{\sqrt{2\pi}\dot{\sigma}_2} e^{-\frac{\dot{r}_2{}^2}{2\dot{\sigma}_2{}^2}} + \\ & P_2\left(1-e^{-\frac{r_T}{2\sigma_1{}^2}}\right)\left(1-e^{-\frac{r_T}{2\sigma_2{}^2}}\right)\frac{1}{\sqrt{2\pi}\dot{\sigma}_2} e^{-\frac{\dot{r}_2{}^2}{2\dot{\sigma}_2{}^2}} + P_2 e^{-\frac{r_T}{2\sigma_2{}^2}} e^{-\frac{r_T}{2\sigma_2{}^2}} \frac{1}{\sqrt{2\pi}\dot{\sigma}_2} e^{-\frac{\dot{r}_2{}^2}{2\dot{\sigma}_2{}^2}} \end{aligned} \tag{4.3.3}$$

Na slici 4.3.1. su prikazane gustine raspodele verovatnoće izvoda signala na izlazu SSC kombinera u dva trenutka vremena i može se videti da su za kanale sa identičnim raspodelama i ove krive identične i prate normalnu raspodelu.



Slika 4.3.1. Gustine raspodele verovatnoće izvoda signala za SSC kombiner u dva trenutka vremena za različite vrednosti $\dot{\sigma}$ u prisustvu Rayleigh-jevog fedinga za parametre $r_T = 1$, $\sigma = 0.1$

4.4 Gustina raspodele verovatnoće izvoda signala na izlazu SSC kombinera u dva trenutka vremena u prisustvu Nakagami-m fedinga

Gustine raspodele verovatnoće izvoda signala na ulazu u kombiner $\dot{r}_{i,j}$ u prisustvu Nakagami-m fedinga imaju normalnu raspodelu sa nultom srednjom vrednošću [16], [19]:

$$p_{\dot{r}_i}(\dot{r}_{i,j}) = \frac{1}{\sqrt{2\pi}\dot{\sigma}_i} e^{-\frac{\dot{r}_{i,j}^{\,2}}{2\dot{\sigma}_i^{\,2}}} \qquad ,-\infty < \dot{r}_{i,j} < \infty \tag{4.4.1}$$

gde su *i=1,2* *j=1,2* i $\dot{\sigma}_i^{\,2} = 2\sigma^2\pi^2 f_m^{\,2}$ je varijansa, dok je f_m maksimalni Doppler-ov frekventni pomeraj.

CDF signala u prisustvu Nakagami-m fedinga je dat u (3.4.2) i na osnovu njega i (4.2.16-17) dobijaju se gustine raspodele verovatnoće izvoda signala $\dot{r}_1$ i $\dot{r}_2$:

$$\begin{aligned} p_{\dot{r}_1}(\dot{r}_1) = {} & P_1\left(1-\gamma\left(\frac{m_1}{\Omega_1} r_T^{\,2}, m_1\right)\right)\frac{1}{\sqrt{2\pi}\dot{\sigma}_1} e^{-\frac{\dot{r}_1^{\,2}}{2\dot{\sigma}_1^{\,2}}} + P_2\gamma\left(\frac{m_2}{\Omega_2} r_T^{\,2}, m_2\right)\frac{1}{\sqrt{2\pi}\dot{\sigma}_1} e^{-\frac{\dot{r}_1^{\,2}}{2\dot{\sigma}_1^{\,2}}} + \\ & + P_1\gamma\left(\frac{m_1}{\Omega_1} r_T^{\,2}, m_1\right)\frac{1}{\sqrt{2\pi}\dot{\sigma}_2} e^{-\frac{\dot{r}_1^{\,2}}{2\dot{\sigma}_2^{\,2}}} + P_2 e^{-\frac{r_T}{2\sigma_2^{\,2}}}\left(1-\gamma\left(\frac{m_2}{\Omega_2} r_T^{\,2}, m_2\right)\right) e^{-\frac{\dot{r}_1^{\,2}}{2\dot{\sigma}_2^{\,2}}} \end{aligned} \tag{4.4.2}$$

$$p_{\dot{r}_2}(\dot{r}_2) = P_1\gamma\left(\frac{m_1}{\Omega_1} r_T^{\,2}, m_1\right)\gamma\left(\frac{m_2}{\Omega_2} r_T^{\,2}, m_2\right)\frac{1}{\sqrt{2\pi}\dot{\sigma}_1} e^{-\frac{\dot{r}_2^{\,2}}{2\dot{\sigma}_1^{\,2}}} +$$

$$P_1\left(1-\gamma\left(\frac{m_1}{\Omega_1}r_T{}^2,m_1\right)\right)\left(1-\gamma\left(\frac{m_1}{\Omega_1}r_T{}^2,m_1\right)\right)\frac{1}{\sqrt{2\pi}\dot{\sigma}_1}e^{-\frac{\dot{r}_2{}^2}{2\dot{\sigma}_1{}^2}}+$$

$$+P_2\gamma\left(\frac{m_2}{\Omega_2}r_T{}^2,m_2\right)\left(1-\gamma\left(\frac{m_2}{\Omega_2}r_T{}^2,m_2\right)\right)\frac{1}{\sqrt{2\pi}\dot{\sigma}_1}e^{-\frac{\dot{r}_2{}^2}{2\dot{\sigma}_1{}^2}}+$$

$$P_2\left(1-\gamma\left(\frac{m_1}{\Omega_1}r_T{}^2,m_1\right)\right)\gamma\left(\frac{m_2}{\Omega_2}r_T{}^2,m_2\right)\frac{1}{\sqrt{2\pi}\dot{\sigma}_1}e^{-\frac{\dot{r}_2{}^2}{2\dot{\sigma}_1{}^2}}+$$

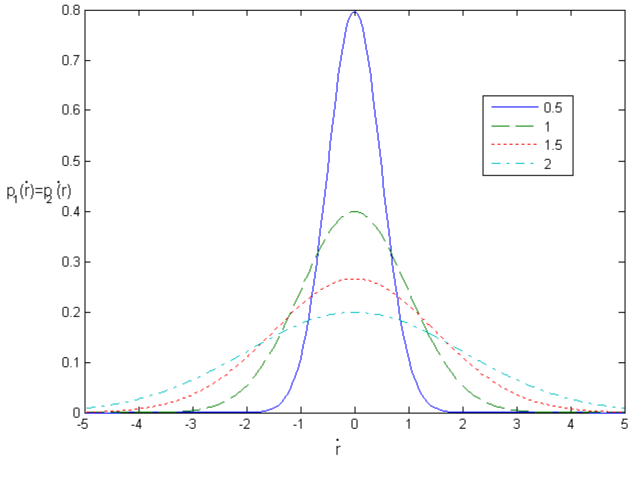
$$+P_1\gamma\left(\frac{m_1}{\Omega_1}r_T{}^2,m_1\right)\left(1-\gamma\left(\frac{m_1}{\Omega_1}r_T{}^2,m_1\right)\right)\frac{1}{\sqrt{2\pi}\dot{\sigma}_2}e^{-\frac{\dot{r}_2{}^2}{2\dot{\sigma}_2{}^2}}+$$

$$P_1\gamma\left(\frac{m_1}{\Omega_1}r_T{}^2,m_1\right)\left(1-\gamma\left(\frac{m_2}{\Omega_2}r_T{}^2,m_2\right)\right)\frac{1}{\sqrt{2\pi}\dot{\sigma}_2}e^{-\frac{\dot{r}_2{}^2}{2\dot{\sigma}_2{}^2}}+$$

$$P_2\gamma\left(\frac{m_1}{\Omega_1}r_T{}^2,m_1\right)\gamma\left(\frac{m_2}{\Omega_2}r_T{}^2,m_2\right)\frac{1}{\sqrt{2\pi}\dot{\sigma}_2}e^{-\frac{\dot{r}_2{}^2}{2\dot{\sigma}_2{}^2}}+$$

$$P_2\left(1-\gamma\left(\frac{m_2}{\Omega_2}r_T{}^2,m_2\right)\right)\left(1-\gamma\left(\frac{m_2}{\Omega_2}r_T{}^2,m_2\right)\right)\frac{1}{\sqrt{2\pi}\dot{\sigma}_2}e^{-\frac{\dot{r}_2{}^2}{2\dot{\sigma}_2{}^2}} \quad (4.4.3)$$

PDF izvoda signala na izlazu SSC kombinera u dva trenutka vremena su date na slici 4.4.1. za kanale sa identičnim feding kanalima.



Slika 4.3.1. Gustina raspodele verovatnoće izvoda signala za SSC kombiner u dva trenutka vremena za različite vrednosti $\dot{\sigma}$ u prisustvu Nakagami-m fedinga za parametre: $r_T=1$, $\Omega=1.5$, $m=1$

4.5 Gustina raspodele verovatnoće izvoda signala na izlazu SSC kombinera u dva trenutka vremena u prisustvu Rice-ovog fedinga

Gustine raspodele verovatnoće izvoda signala na ulazu u kombiner $\dot{r}_{i,j}$ u prisustvu Rice-ovog fedinga imaju normalnu raspodelu sa nultom srednjom vrednošću [318,319]:

$$p_{\dot{r}_i}(\dot{r}_{i,j}) = \frac{1}{\sqrt{2\pi}\dot{\sigma}_i} e^{-\frac{\dot{r}_{i,j}^2}{2\dot{\sigma}_i^2}} \quad , -\infty < \dot{r}_{i,j} < \infty \tag{4.5.1}$$

gde su $i=1,2$ $j=1,2$ i $\dot{\sigma}_i^2 = 2\sigma^2\pi^2 f_m^2$ je varijansa, dok je f_m maksimalni Doppler-ov frekventni pomeraj.

Gustine raspodele verovatnoće izvoda signala $\dot{r}_1$ i $\dot{r}_2$ na izlazu iz SSC kombinera u dva trenutka vremena u prisustvu Rice-ovog fedinga se dobijaju na isti način kao za Rayleigh-jev i Nakagami-m fading, gde je CDF signala dat u (3.5.2).

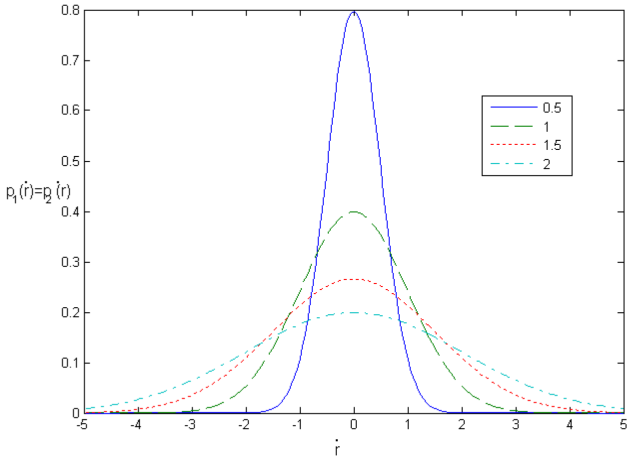
$$\begin{aligned} p_{\dot{r}_1}(\dot{r}_1) = {} & P_1 Q_1\left(\frac{A_1}{\sigma_1}, \frac{r_T}{\sigma_1}\right) \frac{1}{\sqrt{2\pi}\dot{\sigma}_1} e^{-\frac{\dot{r}_1^2}{2\dot{\sigma}_1^2}} + P_2\left(1 - Q_1\left(\frac{A_2}{\sigma_2}, \frac{r_T}{\sigma_2}\right)\right) \frac{1}{\sqrt{2\pi}\dot{\sigma}_1} e^{-\frac{\dot{r}_1^2}{2\dot{\sigma}_1^2}} + \\ & + P_1\left(1 - Q_1\left(\frac{A_1}{\sigma_1}, \frac{r_T}{\sigma_1}\right)\right) \frac{1}{\sqrt{2\pi}\dot{\sigma}_2} e^{-\frac{\dot{r}_1^2}{2\dot{\sigma}_2^2}} + P_2 Q_1\left(\frac{A_2}{\sigma_2}, \frac{r_T}{\sigma_2}\right) \frac{1}{\sqrt{2\pi}\dot{\sigma}_2} e^{-\frac{\dot{r}_1^2}{2\dot{\sigma}_2^2}} \end{aligned} \tag{4.5.2}$$

$$\begin{aligned} p_{\dot{r}_2}(\dot{r}_2) = {} & P_1\left(1 - Q_1\left(\frac{A_1}{\sigma_1}, \frac{r_T}{\sigma_1}\right)\right)\left(1 - Q_1\left(\frac{A_2}{\sigma_2}, \frac{r_T}{\sigma_2}\right)\right) \frac{1}{\sqrt{2\pi}\dot{\sigma}_1} e^{-\frac{\dot{r}_2^2}{2\dot{\sigma}_1^2}} + \\ & P_1 Q_1\left(\frac{A_1}{\sigma_1}, \frac{r_T}{\sigma_1}\right) Q_1\left(\frac{A_1}{\sigma_1}, \frac{r_T}{\sigma_1}\right) \frac{1}{\sqrt{2\pi}\dot{\sigma}_1} e^{-\frac{\dot{r}_2^2}{2\dot{\sigma}_1^2}} + \\ & + P_2\left(1 - Q_1\left(\frac{A_2}{\sigma_2}, \frac{r_T}{\sigma_2}\right)\right) Q_1\left(\frac{A_2}{\sigma_2}, \frac{r_T}{\sigma_2}\right) \frac{1}{\sqrt{2\pi}\dot{\sigma}_1} e^{-\frac{\dot{r}_2^2}{2\dot{\sigma}_1^2}} + \\ & P_2 Q_1\left(\frac{A_1}{\sigma_1}, \frac{r_T}{\sigma_1}\right)\left(1 - Q_1\left(\frac{A_2}{\sigma_2}, \frac{r_T}{\sigma_2}\right)\right) \frac{1}{\sqrt{2\pi}\dot{\sigma}_1} e^{-\frac{\dot{r}_2^2}{2\dot{\sigma}_1^2}} + \\ & + P_1\left(1 - Q_1\left(\frac{A_1}{\sigma_1}, \frac{r_T}{\sigma_1}\right)\right) Q_1\left(\frac{A_1}{\sigma_1}, \frac{r_T}{\sigma_1}\right) \frac{1}{\sqrt{2\pi}\dot{\sigma}_2} e^{-\frac{\dot{r}_2^2}{2\dot{\sigma}_2^2}} + \\ & P_1\left(1 - Q_1\left(\frac{A_1}{\sigma_1}, \frac{r_T}{\sigma_1}\right)\right) Q_1\left(\frac{A_2}{\sigma_2}, \frac{r_T}{\sigma_2}\right) \frac{1}{\sqrt{2\pi}\dot{\sigma}_2} e^{-\frac{\dot{r}_2^2}{2\dot{\sigma}_2^2}} + \end{aligned}$$

$$P_2\left(1-Q_1\left(\frac{A_1}{\sigma_1},\frac{r_T}{\sigma_1}\right)\right)\left(1-Q_1\left(\frac{A_2}{\sigma_2},\frac{r_T}{\sigma_2}\right)\right)\frac{1}{\sqrt{2\pi}\dot{\sigma}_2}e^{-\frac{\dot{r}_2{}^2}{2\dot{\sigma}_2{}^2}}+$$

$$P_2Q_1\left(\frac{A_2}{\sigma_2},\frac{r_T}{\sigma_2}\right)Q_1\left(\frac{A_2}{\sigma_2},\frac{r_T}{\sigma_2}\right)\frac{1}{\sqrt{2\pi}\dot{\sigma}_2}e^{-\frac{\dot{r}_2{}^2}{2\dot{\sigma}_2{}^2}} \tag{4.5.3}$$

Na slici 4.5.1. su prikazane gustine raspodele verovatnoće izvoda signala na izlazu SSC kombinera u prisustvu Rice-ovog fedinga



Slika 4.5.1. Gustine raspodele verovatnoće izvoda signala za SSC kombiner u dva trenutka vremena za različite vrednosti $\dot{\sigma}$ u prisustvu Rice-ovog fedinga za parametre $A=1$, $\sigma=0.5$, $r_T=1$

4.6 Združena gustina raspodele verovatnoće signala i izvoda signala na izlazu SSC kombinera u dva trenutka vremena u prisustvu Weibull-ovog fedinga

Združene gustine raspodele verovatnoće signala $r_{i,j}$ i izvoda signala na ulazu u kombiner $\dot{r}_{i,j}$ su [17]:

$$p_{r_i\dot{r}_i}(r_{i,j},\dot{r}_{i,j})=\frac{\beta_i{}^2 r_{i,j}{}^{(3\beta_i/2)-2}}{f_m(2\pi\Omega_i)^{3/2}}e^{-\frac{\beta_i{}^2 r_{i,j}{}^{\beta_i-2}\dot{r}_{i,j}{}^2}{8\pi^2 f_m{}^2\Omega_i}-\frac{r_{i,j}{}^{\beta_i}}{\Omega_i}} \qquad ,-\infty<\dot{r}_{i,j}<\infty \tag{4.6.1}$$

gde su $i=1,2$ $j=1,2$, β_i predstavlja Weibull-ov feding parametar i pozitivna je realna konstanta i $\Omega_i=E\left(r_{i,j}{}^{\beta_i}\right)$.

Združene gustine raspodele verovatnoće signala i izvoda na izlazu iz SSC kombinera u dva trenutka vremena u prisustvu Weibull-ovog fedinga se dobijaju na osnovu (4.2.11-14). Za $r_1<r_T$, $p_{r_1\dot{r}_1}(r_1,\dot{r}_1)$ je:

$$p_{r_1\dot{r}_1}(r_1,\dot{r}_1)=P_1\frac{\beta_2{}^2 r_1{}^{(3\beta_2/2)-2}}{f_m(2\pi\Omega_2)^{3/2}}e^{-\frac{\beta_2{}^2 r_1{}^{\beta_2-2}\dot{r}_1{}^2}{8\pi^2 f_m{}^2\Omega_2}-\frac{r_1{}^{\beta_2}}{\Omega_2}}F_1(r_T)F_2(r_T)+P_2\frac{\beta_1{}^2 r_1{}^{(3\beta_1/2)-2}}{f_m(2\pi\Omega_1)^{3/2}}e^{-\frac{\beta_1{}^2 r_1{}^{\beta_1-2}\dot{r}_1{}^2}{8\pi^2 f_m{}^2\Omega_1}-\frac{r_1{}^{\beta_1}}{\Omega_1}}F_1(r_T)F_2(r_T)+$$

$$+P_1\frac{\beta_2{}^2 r_1{}^{(3\beta_2/2)-2}}{f_m(2\pi\Omega_2)^{3/2}}e^{-\frac{\beta_2{}^2 r_1{}^{\beta_2-2}\dot{r}_1{}^2}{8\pi^2 f_m{}^2\Omega_2}-\frac{r_1{}^{\beta_2}}{\Omega_2}}F_1(r_T)\int_{r_T}^{\infty}dr_2\int_{-\infty}^{\infty}d\dot{r}_2\frac{\beta_2{}^2 r_2{}^{(3\beta_2/2)-2}}{f_m(2\pi\Omega_2)^{3/2}}e^{-\frac{\beta_2{}^2 r_2{}^{\beta_2-2}\dot{r}_2{}^2}{8\pi^2 f_m{}^2\Omega_2}-\frac{r_2{}^{\beta_2}}{\Omega_2}}+$$

$$+P_2\frac{\beta_1{}^2 r_1{}^{(3\beta_1/2)-2}}{f_m(2\pi\Omega_1)^{3/2}}e^{-\frac{\beta_1{}^2 r_1{}^{\beta_1-2}\dot{r}_1{}^2}{8\pi^2 f_m{}^2\Omega_1}-\frac{r_1{}^{\beta_1}}{\Omega_1}}F_2(r_T)\int_{r_T}^{\infty}dr_2\int_{-\infty}^{\infty}d\dot{r}_2\,p_1(r_2,\dot{r}_2) \tag{4.6.2}$$

Za *r₁*≥*r_T*, $p_{r_1\dot{r}_1}(r_1,\dot{r}_1)$ je:

$$p_{r_1\dot{r}_1}(r_1,\dot{r}_1)=P_1\frac{\beta_1{}^2 r_1{}^{(3\beta_1/2)-2}}{f_m(2\pi\Omega_1)^{3/2}}e^{-\frac{\beta_1{}^2 r_1{}^{\beta_1-2}\dot{r}_1{}^2}{8\pi^2 f_m{}^2\Omega_1}-\frac{r_1{}^{\beta_1}}{\Omega_1}}F_1(r_T)+\ P_1\frac{\beta_2{}^2 r_1{}^{(3\beta_2/2)-2}}{f_m(2\pi\Omega_2)^{3/2}}e^{-\frac{\beta_2{}^2 r_1{}^{\beta_2-2}\dot{r}_1{}^2}{8\pi^2 f_m{}^2\Omega_2}-\frac{r_1{}^{\beta_2}}{\Omega_2}}F_1(r_T)F_2(r_T)+$$

$$\mathrm{h}+P_2\frac{\beta_2{}^2 r_1{}^{(3\beta_2/2)-2}}{f_m(2\pi\Omega_2)^{3/2}}e^{-\frac{\beta_2{}^2 r_1{}^{\beta_2-2}\dot{r}_1{}^2}{8\pi^2 f_m{}^2\Omega_2}-\frac{r_1{}^{\beta_2}}{\Omega_2}}F_2(r_T)+\ P_2\frac{\beta_1{}^2 r_1{}^{(3\beta_1/2)-2}}{f_m(2\pi\Omega_1)^{3/2}}e^{-\frac{\beta_1{}^2 r_1{}^{\beta_1-2}\dot{r}_1{}^2}{8\pi^2 f_m{}^2\Omega_1}-\frac{r_1{}^{\beta_1}}{\Omega_1}}F_1(r_T)F_2(r_T)+$$

$$+P_1\frac{\beta_1{}^2 r_1{}^{(3\beta_1/2)-2}}{f_m(2\pi\Omega_1)^{3/2}}e^{-\frac{\beta_1{}^2 r_1{}^{\beta_1-2}\dot{r}_1{}^2}{8\pi^2 f_m{}^2\Omega_1}-\frac{r_1{}^{\beta_1}}{\Omega_1}}\int_{r_T}^{\infty}dr_2\int_{-\infty}^{\infty}d\dot{r}_2\,p_1(r_2,\dot{r}_2)+$$

$$P_1\frac{\beta_2{}^2 r_1{}^{(3\beta_2/2)-2}}{f_m(2\pi\Omega_2)^{3/2}}e^{-\frac{\beta_2{}^2 r_1{}^{\beta_2-2}\dot{r}_1{}^2}{8\pi^2 f_m{}^2\Omega_2}-\frac{r_1{}^{\beta_2}}{\Omega_2}}F_1(r_T)\int_{r_T}^{\infty}dr_2\int_{-\infty}^{\infty}d\dot{r}_2\frac{\beta_2{}^2 r_2{}^{(3\beta_2/2)-2}}{f_m(2\pi\Omega_2)^{3/2}}e^{-\frac{\beta_2{}^2 r_2{}^{\beta_2-2}\dot{r}_2{}^2}{8\pi^2 f_m{}^2\Omega_2}-\frac{r_2{}^{\beta_2}}{\Omega_2}}+$$

$$+P_2\frac{\beta_2{}^2 r_1{}^{(3\beta_2/2)-2}}{f_m(2\pi\Omega_2)^{3/2}}e^{-\frac{\beta_2{}^2 r_1{}^{\beta_2-2}\dot{r}_1{}^2}{8\pi^2 f_m{}^2\Omega_2}-\frac{r_1{}^{\beta_2}}{\Omega_2}}\int_{r_T}^{\infty}dr_2\int_{-\infty}^{\infty}d\dot{r}_2\frac{\beta_2{}^2 r_2{}^{(3\beta_2/2)-2}}{f_m(2\pi\Omega_2)^{3/2}}e^{-\frac{\beta_2{}^2 r_2{}^{\beta_2-2}\dot{r}_2{}^2}{8\pi^2 f_m{}^2\Omega_2}-\frac{r_2{}^{\beta_2}}{\Omega_2}}+$$

$$P_2\frac{\beta_1{}^2 r_1{}^{(3\beta_1/2)-2}}{f_m(2\pi\Omega_1)^{3/2}}e^{-\frac{\beta_1{}^2 r_1{}^{\beta_1-2}\dot{r}_1{}^2}{8\pi^2 f_m{}^2\Omega_1}-\frac{r_1{}^{\beta_1}}{\Omega_1}}F_2(r_T)\int_{r_T}^{\infty}dr_2\int_{-\infty}^{\infty}d\dot{r}_2\,p_1(r_2,\dot{r}_2) \tag{4.6.3}$$

Za *r₂*<*r_T*, $p_{r_2\dot{r}_2}(r_2,\dot{r}_2)$ je:

$$p_{r_2\dot{r}_2}(r_2,\dot{r}_2)=P_1\frac{\beta_1{}^2 r_2{}^{(3\beta_1/2)-2}}{f_m(2\pi\Omega_1)^{3/2}}e^{-\frac{\beta_1{}^2 r_2{}^{\beta_1-2}\dot{r}_2{}^2}{8\pi^2 f_m{}^2\Omega_1}-\frac{r_2{}^{\beta_1}}{\Omega_1}}F_1(r_T)F_2(r_T)+$$

$$P_2\frac{\beta_2{}^2 r_2{}^{(3\beta_2/2)-2}}{f_m(2\pi\Omega_2)^{3/2}}e^{-\frac{\beta_2{}^2 r_2{}^{\beta_2-2}\dot{r}_2{}^2}{8\pi^2 f_m{}^2\Omega_2}-\frac{r_2{}^{\beta_2}}{\Omega_2}}F_1(r_T)F_2(r_T)+$$

$$+P_1\frac{\beta_2{}^2 r_2{}^{(3\beta_2/2)-2}}{f_m(2\pi\Omega_2)^{3/2}}e^{-\frac{\beta_2{}^2 r_2{}^{\beta_2-2}\dot{r}_2{}^2}{8\pi^2 f_m{}^2\Omega_2}-\frac{r_2{}^{\beta_2}}{\Omega_2}}F_1(r_T)\int_{r_T}^{\infty}dr_1\int_{-\infty}^{\infty}d\dot{r}_1\frac{\beta_1{}^2 r_1{}^{(3\beta_1/2)-2}}{f_m(2\pi\Omega_1)^{3/2}}e^{-\frac{\beta_1{}^2 r_1{}^{\beta_1-2}\dot{r}_1{}^2}{8\pi^2 f_m{}^2\Omega_1}-\frac{r_1{}^{\beta_1}}{\Omega_1}}+$$

$$P_2\frac{\beta_1{}^2 r_2{}^{(3\beta_1/2)-2}}{f_m(2\pi\Omega_1)^{3/2}}e^{-\frac{\beta_1{}^2 r_2{}^{\beta_1-2}\dot{r}_2{}^2}{8\pi^2 f_m{}^2\Omega_1}-\frac{r_2{}^{\beta_1}}{\Omega_1}}F_2(r_T)\int_{r_T}^{\infty}dr_1\int_{-\infty}^{\infty}d\dot{r}_1\frac{\beta_2{}^2 r_1{}^{(3\beta_2/2)-2}}{f_m(2\pi\Omega_2)^{3/2}}e^{-\frac{\beta_2{}^2 r_1{}^{\beta_2-2}\dot{r}_1{}^2}{8\pi^2 f_m{}^2\Omega_2}-\frac{r_1{}^{\beta_2}}{\Omega_2}} \tag{4.6.4}$$

Za $r_2 \geq r_T$, $p_{r_2\dot{r}_2}(r_2,\dot{r}_2)$ je:

$$\begin{aligned}
p_{r_2\dot{r}_2}(r_2,\dot{r}_2) &= P_1 \frac{\beta_1^{\,2} r_2^{(3\beta_1/2)-2}}{f_m(2\pi\Omega_1)^{3/2}} e^{-\frac{\beta_1^{\,2} r_2^{\beta_1-2}\dot{r}_2^{\,2}}{8\pi^2 f_m^{\,2}\Omega_1}-\frac{r_2^{\beta_1}}{\Omega_1}} F_1(r_T)F_2(r_T) + P_1 \frac{\beta_2^{\,2} r_2^{(3\beta_2/2)-2}}{f_m(2\pi\Omega_2)^{3/2}} e^{-\frac{\beta_2^{\,2} r_2^{\beta_2-2}\dot{r}_2^{\,2}}{8\pi^2 f_m^{\,2}\Omega_2}-\frac{r_2^{\beta_2}}{\Omega_2}} F_1(r_T) + \\
&+ P_2 \frac{\beta_1^{\,2} r_2^{(3\beta_1/2)-2}}{f_m(2\pi\Omega_1)^{3/2}} e^{-\frac{\beta_1^{\,2} r_2^{\beta_1-2}\dot{r}_2^{\,2}}{8\pi^2 f_m^{\,2}\Omega_1}-\frac{r_2^{\beta_1}}{\Omega_1}} F_2(r_T) + P_2 \frac{\beta_2^{\,2} r_2^{(3\beta_2/2)-2}}{f_m(2\pi\Omega_2)^{3/2}} e^{-\frac{\beta_2^{\,2} r_2^{\beta_2-2}\dot{r}_2^{\,2}}{8\pi^2 f_m^{\,2}\Omega_2}-\frac{r_2^{\beta_2}}{\Omega_2}} F_1(r_T)F_2(r_T) + \\
&+ P_1 \frac{\beta_1^{\,2} r_2^{(3\beta_1/2)-2}}{f_m(2\pi\Omega_1)^{3/2}} e^{-\frac{\beta_1^{\,2} r_2^{\beta_1-2}\dot{r}_2^{\,2}}{8\pi^2 f_m^{\,2}\Omega_1}-\frac{r_2^{\beta_1}}{\Omega_1}} \int_{r_T}^{\infty} dr_1 \int_{-\infty}^{\infty} d\dot{r}_1 \frac{\beta_1^{\,2} r_1^{(3\beta_1/2)-2}}{f_m(2\pi\Omega_1)^{3/2}} e^{-\frac{\beta_1^{\,2} r_1^{\beta_1-2}\dot{r}_1^{\,2}}{8\pi^2 f_m^{\,2}\Omega_1}-\frac{r_1^{\beta_1}}{\Omega_1}} + \\
&P_1 \frac{\beta_2^{\,2} r_2^{(3\beta_2/2)-2}}{f_m(2\pi\Omega_2)^{3/2}} e^{-\frac{\beta_2^{\,2} r_2^{\beta_2-2}\dot{r}_2^{\,2}}{8\pi^2 f_m^{\,2}\Omega_2}-\frac{r_2^{\beta_2}}{\Omega_2}} F_1(r_T) \int_{r_T}^{\infty} dr_1 \int_{-\infty}^{\infty} d\dot{r}_1 \frac{\beta_1^{\,2} r_1^{(3\beta_1/2)-2}}{f_m(2\pi\Omega_1)^{3/2}} e^{-\frac{\beta_1^{\,2} r_1^{\beta_1-2}\dot{r}_1^{\,2}}{8\pi^2 f_m^{\,2}\Omega_1}-\frac{r_1^{\beta_1}}{\Omega_1}} + \\
&+ P_2 \frac{\beta_1^{\,2} r_2^{(3\beta_1/2)-2}}{f_m(2\pi\Omega_1)^{3/2}} e^{-\frac{\beta_1^{\,2} r_2^{\beta_1-2}\dot{r}_2^{\,2}}{8\pi^2 f_m^{\,2}\Omega_1}-\frac{r_2^{\beta_1}}{\Omega_1}} F_2(r_T) \int_{r_T}^{\infty} dr_1 \int_{-\infty}^{\infty} d\dot{r}_1 \frac{\beta_2^{\,2} r_1^{(3\beta_2/2)-2}}{f_m(2\pi\Omega_2)^{3/2}} e^{-\frac{\beta_2^{\,2} r_1^{\beta_2-2}\dot{r}_1^{\,2}}{8\pi^2 f_m^{\,2}\Omega_2}-\frac{r_1^{\beta_2}}{\Omega_2}} + \\
&P_2 \frac{\beta_2^{\,2} r_2^{(3\beta_2/2)-2}}{f_m(2\pi\Omega_2)^{3/2}} e^{-\frac{\beta_2^{\,2} r_2^{\beta_2-2}\dot{r}_2^{\,2}}{8\pi^2 f_m^{\,2}\Omega_2}-\frac{r_2^{\beta_2}}{\Omega_2}} \int_{r_T}^{\infty} dr_1 \int_{-\infty}^{\infty} d\dot{r}_1 \frac{\beta_2^{\,2} r_1^{(3\beta_2/2)-2}}{f_m(2\pi\Omega_2)^{3/2}} e^{-\frac{\beta_2^{\,2} r_1^{\beta_2-2}\dot{r}_1^{\,2}}{8\pi^2 f_m^{\,2}\Omega_2}-\frac{r_1^{\beta_2}}{\Omega_2}} \qquad (4.6.5)
\end{aligned}$$

4.7 Gustina raspodele verovatnoće izvoda signala na izlazu SSC kombinera u dva trenutka vremena u prisustvu log-normalnog fedinga

Gustine raspodele verovatnoće izvoda signala na ulazu u kombiner $\dot{r}_{i,j}$ u prisustvu log-normalnog fedinga imaju normalnu raspodelu sa nultom srednjom vrednošću [60], [62]:

$$p_{\dot{r}_i}(\dot{r}_{i,j}) = \frac{1}{\sqrt{2\pi}\dot{\sigma}_i} e^{-\frac{\dot{r}_{i,j}^{\,2}}{2\dot{\sigma}_i^{\,2}}} \quad ,-\infty < \dot{r}_{i,j} < \infty \qquad (4.7.1)$$

gde su $i=1,2$ $j=1,2$ i $\dot{\sigma}_i^{\,2} = 2\sigma^2\pi^2 f_m^{\,2}$ je varijansa, dok je f_m maksimalni Doppler-ov frekventni pomeraj.

CDF signala u prisustvu log-normalnog fedinga je dat u (3.7.2) i na osnovu njega i (4.2.16-17) dobijaju se gustine raspodele verovatnoće izvoda signala $\dot{r}_1$ i $\dot{r}_2$:

$$p_{\dot{r}_1}(\dot{r}_1) = P_1 Q\left(\frac{\ln r_T - \mu_1}{\sigma_1}\right) \frac{1}{\sqrt{2\pi}\dot{\sigma}_1} e^{-\frac{\dot{r}_1^{\,2}}{2\dot{\sigma}_1^{\,2}}} + P_2\left(1 - Q\left(\frac{\ln r_T - \mu_2}{\sigma_2}\right)\right) \frac{1}{\sqrt{2\pi}\dot{\sigma}_1} e^{-\frac{\dot{r}_1^{\,2}}{2\dot{\sigma}_1^{\,2}}} +$$

$$+P_1\left(1-Q\left(\frac{\ln r_T-\mu_1}{\sigma_1}\right)\right)\frac{1}{\sqrt{2\pi}\dot{\sigma}_2}e^{-\frac{\dot{r}_1^2}{2\dot{\sigma}_2^2}}+P_2Q\left(\frac{\ln r_T-\mu_2}{\sigma_2}\right)\frac{1}{\sqrt{2\pi}\dot{\sigma}_2}e^{-\frac{\dot{r}_1^2}{2\dot{\sigma}_2^2}} \qquad (4.7.2)$$

$$p_{\dot{r}_2}(\dot{r}_2)=P_1\left(1-Q\left(\frac{\ln r_T-\mu_1}{\sigma_1}\right)\right)\left(1-Q\left(\frac{\ln r_T-\mu_2}{\sigma_2}\right)\right)\frac{1}{\sqrt{2\pi}\dot{\sigma}_1}e^{-\frac{\dot{r}_2^2}{2\dot{\sigma}_1^2}}+$$

$$P_1Q\left(\frac{\ln r_T-\mu_1}{\sigma_1}\right)Q\left(\frac{\ln r_T-\mu_1}{\sigma_1}\right)\frac{1}{\sqrt{2\pi}\dot{\sigma}_1}e^{-\frac{\dot{r}_2^2}{2\dot{\sigma}_1^2}}+$$

$$+P_2\left(1-Q\left(\frac{\ln r_T-\mu_2}{\sigma_2}\right)\right)Q\left(\frac{\ln r_T-\mu_2}{\sigma_2}\right)\frac{1}{\sqrt{2\pi}\dot{\sigma}_1}e^{-\frac{\dot{r}_2^2}{2\dot{\sigma}_1^2}}+$$

$$P_2Q\left(\frac{\ln r_T-\mu_1}{\sigma_1}\right)\left(1-Q\left(\frac{\ln r_T-\mu_2}{\sigma_2}\right)\right)\frac{1}{\sqrt{2\pi}\dot{\sigma}_1}e^{-\frac{\dot{r}_2^2}{2\dot{\sigma}_1^2}}+$$

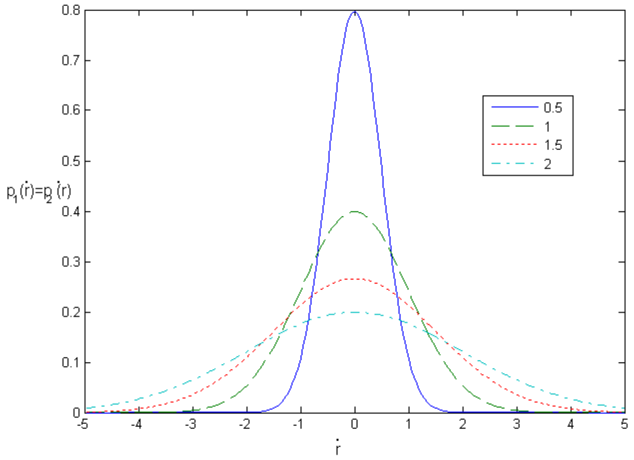
$$+P_1\left(1-Q\left(\frac{\ln r_T-\mu_1}{\sigma_1}\right)\right)Q\left(\frac{\ln r_T-\mu_1}{\sigma_1}\right)\frac{1}{\sqrt{2\pi}\dot{\sigma}_2}e^{-\frac{\dot{r}_2^2}{2\dot{\sigma}_2^2}}+$$

$$P_1\left(1-Q\left(\frac{\ln r_T-\mu_1}{\sigma_1}\right)\right)Q\left(\frac{\ln r_T-\mu_2}{\sigma_2}\right)\frac{1}{\sqrt{2\pi}\dot{\sigma}_2}e^{-\frac{\dot{r}_2^2}{2\dot{\sigma}_2^2}}+$$

$$P_2\left(1-Q\left(\frac{\ln r_T-\mu_1}{\sigma_1}\right)\right)\left(1-Q\left(\frac{\ln r_T-\mu_2}{\sigma_2}\right)\right)\frac{1}{\sqrt{2\pi}\dot{\sigma}_2}e^{-\frac{\dot{r}_2^2}{2\dot{\sigma}_2^2}}+$$

$$P_2Q\left(\frac{\ln r_T-\mu_2}{\sigma_2}\right)Q\left(\frac{\ln r_T-\mu_2}{\sigma_2}\right)\frac{1}{\sqrt{2\pi}\dot{\sigma}_2}e^{-\frac{\dot{r}_2^2}{2\dot{\sigma}_2^2}} \qquad (4.7.3)$$

Na slici 4.7.1. su prikazane PDF izvoda signala na izlazu SSC kombinera u dva trenutka vremena. Sa kojih se vid da su za kanale sa identičnim raspodelama i ove krive identične.



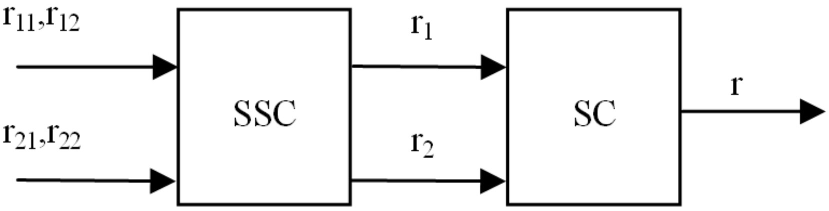
Slika 4.7.1. Gustine raspodele verovatnoće izvoda signala za SSC kombiner u dva trenutka vremena za različite vrednosti $\dot{\sigma}$ u prisustvu log-normalnog fedinga za parametre $r_T=1$, $\sigma=1$, $\mu=0.5$

5 Karakteristike SSC/SC kombinera

U petoj glavi će biti dobijeni parametri složenog SSC/SC prijemnika u dva trenutka vremena, kada signali na izlazu iz SSC kombinera razmatranog u trećoj glavi predstavljaju ulaze u SC kombiner, tako da je izlazni signal iz složenog kombinera jednak najboljoj vrednosti signala na izlayu is SSC kombinera.

5.1 Model sistema u dva trenutka vremena

U ovom poglavlju se razmatra SSC/SC kombiner sa dve grane u dva trenutka vremena. Model sistema je prikazan na slici 5.1.1. Signali na ulazima su r_{11} i r_{21} u prvom trenutku vremena, a r_{12} i r_{22} u drugom trenutku vremena. Indeksi za ulazne signale su: prvi indeks je broj grane, a drugi razmatran vremenski trenutak. Verovatnoća da kombiner prvo razmatra signal na prvoj grani je P_1, a na drugoj je P_2. Signali na izlazu iz SSC kombinera su r_1 i r_2, gde indeks predstavlja razmatrani vremenski trenutak. Signal na izlazu iz složenog kombinera je r.



Slika 5.1.1. Model SSC/SC kombinera sa dva ulaza u dva trenutka vremena

Gustina raspodele verovatnoće signala na izlazu iz SSC/SC kombinera se dobija na oslovu združenih gustina raspodela verovatnoća signala na izlazima iz SSC kombinera u dva trenutka vremena, zavisno od oblasti u kojoj se signali nalaze:

Za slučaj $r<r_T$ $(r_1<r_T,\ r_2<r_T)$

$$p_r(r)=\int_0^r p_{r_1,r_2}(r,r_2)dr_2+\int_0^r p_{r_1,r_2}(r_1,r)dr_1 \tag{5.1.1}$$

Za slučaj $r\geq r_T$ $(r_1<r_T,\ r_2\geq r_T)$

$$p_{r_1}(r)=\int_0^{r_T} p_{r_1,r_2}(r,r_2)dr_2+\int_{r_T}^r p_{r_1,r_2}(r_1,r)dr_1 \tag{5.1.2}$$

Za slučaj $r\geq r_T$ $(r_1\geq r_T,\ r_2<r_T)$

$$p_{r_2}(r)=\int_{r_T}^r p_{r_1,r_2}(r,r_2)dr_2+\int_0^{r_T} p_{r_1,r_2}(r_1,r)dr_1 \tag{5.1.3}$$

Za slučaj $r\geq r_T$ $(r_1<r_T,\ r_2\geq r_T)$

$$p_{r_3}(r)=\int_{r_T}^r p_{r_1,r_2}(r,r_2)dr_2+\int_{r_T}^r p_{r_1,r_2}(r_1,r)dr_1 \tag{5.1.4}$$

Ukupna gustina raspodele verovatnoće signala na izlazu, za $r\geq r_T$ je:

$$p_r(r)=p_{r_1}(r)+p_{r_2}(r)+p_{r_3}(r) \tag{5.1.5}$$

Verovatnoća otkaza $P_{out}(r)=P(r_1\leq r,r_2\leq r)$ se dobija na osnovu PDF signala i može se predstaviti na sledeći način:

Za slučaj $r<r_T$ $(r_1<r_T,\ r_2<r_T)$

$$P_{out}(r)=\int_0^r p_r(r)dr \tag{5.1.6}$$

Za slučaj $r\geq r_T$ $(r_1\geq r_T,\ r_2<r_T,\ r_1\geq r_T,\ r_2\geq r_T,\ r_1\geq r_T,\ r_2\geq r_T)$

$$P_{out}(r)=\int_0^{r_t} p_r(r)dr+\int_{r_t}^r p_r(r)dr \tag{5.1.7}$$

5.2 Karakteristike SSC/SC kombinera u dva trenutka vremena u prisustvu Rayleigh-jevog fedinga

Gustina raspodele verovatnoće signala na izlazu iz SSC/SC kombinera u prisustvu Rayleigh-jevog fedinga se dobija na oslovu združenih gustina raspodela verovatnoća signala na izlazima iz SSC kombinera u dva trenutka vremena (3.3.16-19) i izraza (5.1.1-6).

Za slučaj $r<r_T$ $(r_1<r_T,\ r_2<r_T)$

$$p_r(r)=2\frac{r}{\sigma^2}e^{-\frac{r^2}{2\sigma^2}}\left[1-Q_1\left(\frac{\rho r}{\sigma\sqrt{1-\rho^2}},\frac{r_t}{\sigma\sqrt{1-\rho^2}}\right)\right]\cdot$$

$$\cdot\left[1-e^{-\frac{r^2}{2\sigma^2}}-e^{-\frac{r_t^2}{2\sigma^2}}Q_1\left(\frac{r}{\sigma}\sqrt{\frac{1}{(1-\rho^2)}},\frac{\rho r_t}{\sigma\sqrt{1-\rho^2}}\right)+e^{-\frac{r^2}{2\sigma^2}}Q_1\left(\frac{r\rho}{\sigma\sqrt{1-\rho^2}},\frac{r_t}{\sigma\sqrt{1-\rho^2}}\right)\right] \tag{5.2.1}$$

Za slučaj $r\geq r_T$ $(r_1\geq r_T,\ r_2<r_T,\ r_1\geq r_T,\ r_2\geq r_T,\ r_1\geq r_T,\ r_2\geq r_T)$

$$p_r(r)=\frac{r}{\sigma^2}e^{-\frac{r^2}{2\sigma^2}}\left[1-Q_1\left(\frac{\rho r}{\sigma\sqrt{1-\rho^2}},\frac{r_t}{\sigma\sqrt{1-\rho^2}}\right)\right]\cdot$$

$$\cdot\left[4-2e^{-\frac{r_t^2}{2\sigma^2}}-2e^{-\frac{r}{2\sigma^2}}-e^{-\frac{r_t^2}{2\sigma^2}}Q_1\left(\frac{r_t}{\sigma}\sqrt{\frac{1}{(1-\rho^2)}},\frac{\rho r_t}{\sigma\sqrt{1-\rho^2}}\right)+e^{-\frac{r_t^2}{2\sigma^2}}Q_1\left(\frac{r_t\rho}{\sigma\sqrt{1-\rho^2}},\frac{r_t}{\sigma\sqrt{1-\rho^2}}\right)-\right.$$

$$\left.-e^{-\frac{r_t^2}{2\sigma^2}}Q_1\left(\frac{r}{\sigma}\sqrt{\frac{1}{(1-\rho^2)}},\frac{\rho r_t}{\sigma\sqrt{1-\rho^2}}\right)+e^{-\frac{r_t^2}{2\sigma^2}}Q_1\left(\frac{r\rho}{\sigma\sqrt{1-\rho^2}},\frac{r_t}{\sigma\sqrt{1-\rho^2}}\right)\right]+$$

$$+\frac{r}{\sigma^2}e^{-\frac{r^2}{2\sigma^2}}\left[2-Q_1\left(\frac{\rho r}{\sigma\sqrt{1-\rho^2}},\frac{r_t}{\sigma\sqrt{1-\rho^2}}\right)\right]\cdot$$

$$\cdot\left[e^{-\frac{r_t^2}{2\sigma^2}}-e^{-\frac{r}{2\sigma^2}}-e^{-\frac{r_t^2}{2\sigma^2}}Q_1\left(\frac{r}{\sigma}\sqrt{\frac{1}{(1-\rho^2)}},\frac{\rho r_t}{\sigma\sqrt{1-\rho^2}}\right)+e^{-\frac{r_t^2}{2\sigma^2}}Q_1\left(\frac{r\rho}{\sigma\sqrt{1-\rho^2}},\frac{r_t}{\sigma\sqrt{1-\rho^2}}\right)+\right.$$

$$\left.+e^{-\frac{r_t^2}{2\sigma^2}}Q_1\left(\frac{r_t}{\sigma}\sqrt{\frac{1}{(1-\rho^2)}},\frac{\rho r_t}{\sigma\sqrt{1-\rho^2}}\right)-e^{-\frac{r_t^2}{2\sigma^2}}Q_1\left(\frac{r_t\rho}{\sigma\sqrt{1-\rho^2}},\frac{r_t}{\sigma\sqrt{1-\rho^2}}\right)\right] \tag{5.2.2}$$

Izrazi za gustinu raspodele verovatnoće su dobijeni u zatvorenom obliku i povoljni su za proračun ostalih karakteristika sistema.

Verovatnoća otkaza se dobija na osnovu (5.1.6-7) i nakon određenih matematičkih transformacija je takođe dobijena u zatvorenom obliku:

Za slučaj $r<r_T$ $(r_1<r_T,\ r_2<r_T)$

$$P_{out}(r)=\left[1-e^{-\frac{r^2}{2\sigma^2}}-e^{-\frac{r_t^2}{2\sigma^2}}Q_1\left(\frac{r}{\sigma}\sqrt{\frac{1}{\left(1-\rho^2\right)}},\frac{\rho r_t}{\sigma\sqrt{1-\rho^2}}\right)+e^{-\frac{r^2}{2\sigma^2}}Q_1\left(\frac{r\rho}{\sigma\sqrt{1-\rho^2}},\frac{r_t}{\sigma\sqrt{1-\rho^2}}\right)\right]^2 \tag{5.2.3}$$

Za slučaj $r \geq r_T$ ($r_1 \geq r_T$, $r_2 < r_T$, $r_1 \geq r_T$, $r_2 \geq r_T$, $r_1 \geq r_T$, $r_2 \geq r_T$)

$$P_{out}(r)=\left[1-e^{-\frac{r_t^2}{2\sigma^2}}-e^{-\frac{r_t^2}{2\sigma^2}}Q_1\left(\frac{r_t}{\sigma}\sqrt{\frac{1}{\left(1-\rho^2\right)}},\frac{\rho r_t}{\sigma\sqrt{1-\rho^2}}\right)+e^{-\frac{r_t^2}{2\sigma^2}}Q_1\left(\frac{r_t\rho}{\sigma\sqrt{1-\rho^2}},\frac{r_t}{\sigma\sqrt{1-\rho^2}}\right)\right]^2+$$

$$+\left\{\left[1-e^{-\frac{r}{2\sigma^2}}-e^{-\frac{r_t^2}{2\sigma^2}}Q_1\left(\frac{r}{\sigma}\sqrt{\frac{1}{\left(1-\rho^2\right)}},\frac{\rho r_t}{\sigma\sqrt{1-\rho^2}}\right)-e^{-\frac{r_t^2}{2\sigma^2}}Q_1\left(\frac{r\rho}{\sigma\sqrt{1-\rho^2}},\frac{r_t}{\sigma\sqrt{1-\rho^2}}\right)\right]-\right.$$

$$\left.-\left[1-e^{-\frac{r_t^2}{2\sigma^2}}-e^{-\frac{r_t^2}{2\sigma^2}}Q_1\left(\frac{r_t}{\sigma}\sqrt{\frac{1}{\left(1-\rho^2\right)}},\frac{\rho r_t}{\sigma\sqrt{1-\rho^2}}\right)+e^{-\frac{r_t^2}{2\sigma^2}}Q_1\left(\frac{r_t\rho}{\sigma\sqrt{1-\rho^2}},\frac{r_t}{\sigma\sqrt{1-\rho^2}}\right)\right]\right\}\cdot$$

$$\cdot\left[2-2e^{-\frac{r_t^2}{2\sigma^2}}-e^{-\frac{r_t^2}{2\sigma^2}}Q_1\left(\frac{r_t}{\sigma}\sqrt{\frac{1}{\left(1-\rho^2\right)}},\frac{\rho r_t}{\sigma\sqrt{1-\rho^2}}\right)+e^{-\frac{r_t^2}{2\sigma^2}}Q_1\left(\frac{r_t\rho}{\sigma\sqrt{1-\rho^2}},\frac{r_t}{\sigma\sqrt{1-\rho^2}}\right)\right]+$$

$$+\left(1-e^{-\frac{r_t}{2\sigma^2}}\right)\left\{\left[e^{-\frac{r_t^2}{2\sigma^2}}Q_1\left(\frac{r}{\sigma}\sqrt{\frac{1}{\left(1-\rho^2\right)}},\frac{\rho r_t}{\sigma\sqrt{1-\rho^2}}\right)-e^{-\frac{r^2}{2\sigma^2}}Q_1\left(\frac{r\rho}{\sigma\sqrt{1-\rho^2}},\frac{r_t}{\sigma\sqrt{1-\rho^2}}\right)\right]-\right.$$

$$\left.-\left[e^{-\frac{r_t^2}{2\sigma^2}}Q_1\left(\frac{r_t}{\sigma}\sqrt{\frac{1}{\left(1-\rho^2\right)}},\frac{\rho r_t}{\sigma\sqrt{1-\rho^2}}\right)-e^{-\frac{r_t^2}{2\sigma^2}}Q_1\left(\frac{r_t\rho}{\sigma\sqrt{1-\rho^2}},\frac{r_t}{\sigma\sqrt{1-\rho^2}}\right)\right]\right\}+$$

$$+\left\{\left[1-e^{-\frac{r}{2\sigma^2}}-e^{-\frac{r_t^2}{2\sigma^2}}Q_1\left(\frac{r}{\sigma}\sqrt{\frac{1}{\left(1-\rho^2\right)}},\frac{\rho r_t}{\sigma\sqrt{1-\rho^2}}\right)+e^{-\frac{r_t^2}{2\sigma^2}}Q_1\left(\frac{r\rho}{\sigma\sqrt{1-\rho^2}},\frac{r_t}{\sigma\sqrt{1-\rho^2}}\right)\right]-\right.$$

$$\left.-\left[1-e^{-\frac{r_t^2}{2\sigma^2}}-e^{-\frac{r_t^2}{2\sigma^2}}Q_1\left(\frac{r_t}{\sigma}\sqrt{\frac{1}{\left(1-\rho^2\right)}},\frac{\rho r_t}{\sigma\sqrt{1-\rho^2}}\right)+e^{-\frac{r_t^2}{2\sigma^2}}Q_1\left(\frac{r_t\rho}{\sigma\sqrt{1-\rho^2}},\frac{r_t}{\sigma\sqrt{1-\rho^2}}\right)\right]\right\}\cdot$$

$$\cdot\left[1-e^{-\frac{r_t^2}{2\sigma^2}}-e^{-\frac{r_t^2}{2\sigma^2}}Q_1\left(\frac{r_t}{\sigma}\sqrt{\frac{1}{\left(1-\rho^2\right)}},\frac{\rho r_t}{\sigma\sqrt{1-\rho^2}}\right)+e^{-\frac{r_t^2}{2\sigma^2}}Q_1\left(\frac{r_t\rho}{\sigma\sqrt{1-\rho^2}},\frac{r_t}{\sigma\sqrt{1-\rho^2}}\right)\right]+$$

$$+\left(2-e^{-\frac{r_t}{2\sigma^2}}\right)\left\{\left[e^{-\frac{r_t^2}{2\sigma^2}}Q_1\left(\frac{r}{\sigma}\sqrt{\frac{1}{\left(1-\rho^2\right)}},\frac{\rho r_t}{\sigma\sqrt{1-\rho^2}}\right)-e^{-\frac{r^2}{2\sigma^2}}Q_1\left(\frac{r\rho}{\sigma\sqrt{1-\rho^2}},\frac{r_t}{\sigma\sqrt{1-\rho^2}}\right)\right]-\right.$$

$$-\left[e^{-\frac{r_t^2}{2\sigma^2}}Q_1\left(\frac{r_t}{\sigma}\sqrt{\frac{1}{\left(1-\rho^2\right)}},\frac{\rho r_t}{\sigma\sqrt{1-\rho^2}}\right)-e^{-\frac{r_t^2}{2\sigma^2}}Q_1\left(\frac{r_t\rho}{\sigma\sqrt{1-\rho^2}},\frac{r_t}{\sigma\sqrt{1-\rho^2}}\right)\right]-$$

$$-\left[e^{-\frac{r^2}{2\sigma^2}}Q_1\left(\frac{r}{\sigma}\sqrt{\frac{1}{\left(1-\rho^2\right)}},\frac{\rho r}{\sigma\sqrt{1-\rho^2}}\right)-e^{-\frac{r^2}{2\sigma^2}}Q_1\left(\frac{r\rho}{\sigma\sqrt{1-\rho^2}},\frac{r}{\sigma\sqrt{1-\rho^2}}\right)\right]+$$

$$+\Bigg[e^{-\frac{r^2}{2\sigma^2}}Q_1\left(\frac{r_t}{\sigma}\sqrt{\frac{1}{(1-\rho^2)}},\frac{\rho r}{\sigma\sqrt{1-\rho^2}}\right)-e^{-\frac{r_t^2}{2\sigma^2}}Q_1\left(\frac{r_t\rho}{\sigma\sqrt{1-\rho^2}},\frac{r}{\sigma\sqrt{1-\rho^2}}\right)\Bigg]\Bigg]\Bigg\}+$$

$$+\Bigg\{\Bigg[1-e^{-\frac{r}{2\sigma^2}}-e^{-\frac{r_t^2}{2\sigma^2}}Q_1\left(\frac{r}{\sigma}\sqrt{\frac{1}{(1-\rho^2)}},\frac{\rho r_t}{\sigma\sqrt{1-\rho^2}}\right)+e^{-\frac{r_t^2}{2\sigma^2}}Q_1\left(\frac{r\rho}{\sigma\sqrt{1-\rho^2}},\frac{r_t}{\sigma\sqrt{1-\rho^2}}\right)\Bigg]-$$

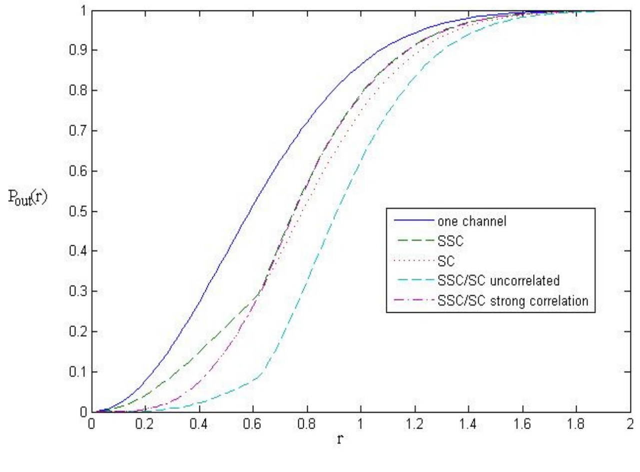
$$-\Bigg[1-e^{-\frac{r_t^2}{2\sigma^2}}-e^{-\frac{r_t^2}{2\sigma^2}}Q_1\left(\frac{r_t}{\sigma}\sqrt{\frac{1}{(1-\rho^2)}},\frac{\rho r_t}{\sigma\sqrt{1-\rho^2}}\right)+e^{-\frac{r_t^2}{2\sigma^2}}Q_1\left(\frac{r_t\rho}{\sigma\sqrt{1-\rho^2}},\frac{r_t}{\sigma\sqrt{1-\rho^2}}\right)\Bigg]\Bigg\}\cdot$$

$$\cdot\Bigg\{\Bigg[2-2e^{-\frac{r}{2\sigma^2}}-e^{-\frac{r_t^2}{2\sigma^2}}Q_1\left(\frac{r}{\sigma}\sqrt{\frac{1}{(1-\rho^2)}},\frac{\rho r_t}{\sigma\sqrt{1-\rho^2}}\right)+e^{-\frac{r_t^2}{2\sigma^2}}Q_1\left(\frac{r\rho}{\sigma\sqrt{1-\rho^2}},\frac{r_t}{\sigma\sqrt{1-\rho^2}}\right)\Bigg]-$$

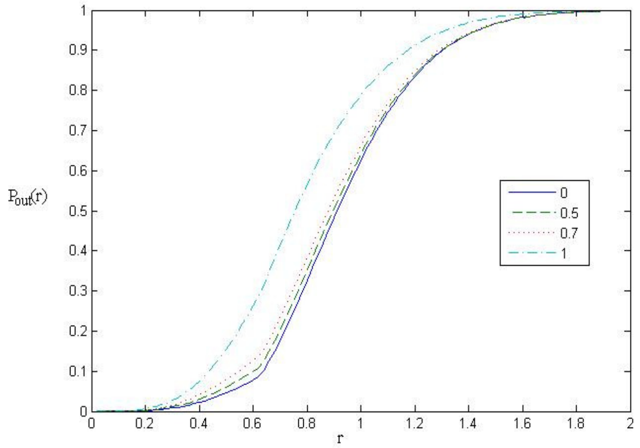
$$-\Bigg[2-2e^{-\frac{r_t^2}{2\sigma^2}}-e^{-\frac{r_t^2}{2\sigma^2}}Q_1\left(\frac{r_t}{\sigma}\sqrt{\frac{1}{(1-\rho^2)}},\frac{\rho r_t}{\sigma\sqrt{1-\rho^2}}\right)+e^{-\frac{r_t^2}{2\sigma^2}}Q_1\left(\frac{r_t\rho}{\sigma\sqrt{1-\rho^2}},\frac{r_t}{\sigma\sqrt{1-\rho^2}}\right)\Bigg]\Bigg\} \tag{5.2.4}$$

Na slici 5.2.1. su prikazane familije kriva za verovatnoće otkaza za različite tipove kombinera u prisustvu Rayleigh-jevog fedinga za jednokanalni prijemnik, SSC i SC prijemnike u jednom trenutku vremena i SSC/SC prijemnik u 2 trenutka vremena u slučajevima bez korelacije i sa veoma jakom korelacijom na ulazima u kombiner. Može se zaključiti da SSC/SC kombiner ima značajno bolje performanse za slučaj bez korelacije, a za slučaj sa jakom korelacijom, $\rho=1$, *SSC/SC* kombiner za $r<r_T$ prati rezultate za SC kombiner u jednom trenutku vremena, a u ostalom delu za SSC kombiner u jednom trenutku vremena.

Kada se analiziraju verovatnoće otkaza za SSC/SC kombinere u 2 trenutka vremena koje su prikazane na slici 5.2.2. jasno se uočava da se benefiti upotrebe ove vrste kombinera povećavaju sa smanjenjem korelacije između ulaznih signala.



Slika 5.2.1. Verovatnoće otkaza za različite tipove kombinera u prisustvu Rayleigh-jevog fedinga za parametre: $\sigma=0.5$, $\rho=0;1$



Slika 5.2.2. Verovatnoće otkaza za SSC/SC kombiner u dva trenutka vremena za različite vrednosti korelacije u prisustvu Rayleigh-jevog fedinga za parametar $\sigma = 0.5$

5.3 Karakteristike SSC/SC kombinera u dva trenutka vremena u prisustvu log-normalnog fedinga

Gustina raspodele verovatnoće signala na izlazu iz SSC/SC kombinera u prisustvu log-normalnog fedinga se dobija na oslovu združenih gustina raspodela verovatnoća signala na izlazima iz SSC kombinera u dva trenutka vremena (3.7.17-20) i izraza (5.1.1-6).

Za slučaj $r<r_T$ $(r_1<r_T, r_2<r_T)$

$$p_r(r) = 2\frac{1}{\sqrt{2\pi}\sigma r} e^{-\frac{(\ln r-\mu)^2}{2\sigma^2}} \left(\frac{1}{2} + erf\left(\frac{\ln r_t - (\mu+\rho(\ln r-\mu))}{\sigma\sqrt{1-\rho^2}\sqrt{2}}\right)\right)\cdot$$

$$\cdot\int_0^r \frac{1}{\sqrt{2\pi}\sigma r_1} e^{-\frac{(\ln r_1-\mu)^2}{2\sigma^2}} \left(\frac{1}{2} + erf\left(\frac{\ln r_t - (\mu+\rho(\ln r_1-\mu))}{\sigma\sqrt{1-\rho^2}\sqrt{2}}\right)\right) dr_1 \qquad (5.3.1)$$

Za slučaj $r \geq r_T$ $(r_1 \geq r_T, r_2 < r_T, r_1 \geq r_T, r_2 \geq r_T, r_1 \geq r_T, r_2 \geq r_T)$

$$p_r(r) = \frac{1}{2\sqrt{2\pi}\sigma r} e^{-\frac{(\ln r-\mu)^2}{2\sigma^2}} \left(\frac{1}{2} + \frac{1}{2} erf\left(\frac{\ln r-\mu}{\sigma\sqrt{2}}\right)\right)\cdot$$

$$\cdot\left(\frac{1}{2} + erf\left(\frac{\ln r_t - (\mu+\rho(\ln r-\mu))}{\sigma\sqrt{1-\rho^2}\sqrt{2}}\right)\right) +$$

$$+\frac{1}{2\sqrt{2\pi}\sigma r} e^{-\frac{(\ln r-\mu)^2}{2\sigma^2}} \cdot\int_0^r \frac{1}{\sqrt{2\pi}\sigma r_1} e^{-\frac{(\ln r_1-\mu)^2}{2\sigma^2}} \left(\frac{1}{2} + erf\left(\frac{\ln r_t - (\mu+\rho(\ln r_1-\mu))}{\sigma\sqrt{1-\rho^2}\sqrt{2}}\right)\right) dr_1 +$$

$$+\frac{1}{\sqrt{2\pi}\sigma r}e^{-\frac{(\ln r-\mu)^2}{2\sigma^2}}\left(\frac{1}{2}+erf\left(\frac{\ln r_t-(\mu+\rho(\ln r-\mu))}{\sigma\sqrt{1-\rho^2}\sqrt{2}}\right)\right)\cdot$$

$$\cdot\int_0^r\frac{1}{\sqrt{2\pi}\sigma r_1}e^{-\frac{(\ln r_1-\mu)^2}{2\sigma^2}}\left(\frac{1}{2}+erf\left(\frac{\ln r_t-(\mu+\rho(\ln r_1-\mu))}{\sigma\sqrt{1-\rho^2}\sqrt{2}}\right)\right)dr_1+$$

$$+\frac{1}{2\pi\sigma^2\sqrt{1-\rho^2}r}\left(\frac{1}{2}+erf\left(\frac{\ln r_t-\mu}{\sigma\sqrt{2}}\right)\right)\cdot$$

$$\cdot\int_0^r\frac{1}{r_1}e^{-\frac{1}{2(1-\rho^2)}\left[\left(\frac{\ln r-\mu}{\sigma}\right)^2+\left(\frac{\ln r_1-\mu}{\sigma}\right)^2-2\rho\left(\frac{\ln r-\mu}{\sigma}\right)\left(\frac{\ln r_1-\mu}{\sigma}\right)\right]}dr_1+$$

$$+\frac{1}{\sqrt{2\pi}\sigma r}e^{-\frac{(\ln r-\mu)^2}{2\sigma^2}}\left(\frac{1}{2}+erf\left(\frac{\ln r_t-(\mu+\rho(\ln r-\mu))}{\sigma\sqrt{1-\rho^2}\sqrt{2}}\right)\right)\cdot$$

$$\cdot\int_0^r\frac{1}{\sqrt{2\pi}\sigma r_1}e^{-\frac{(\ln r_1-\mu)^2}{2\sigma^2}}\left(\frac{1}{2}+erf\left(\frac{\ln r_t-(\mu+\rho(\ln r_1-\mu))}{\sigma\sqrt{1-\rho^2}\sqrt{2}}\right)\right)dr_1+$$

$$+\frac{2}{2\pi\sigma_2{}^2\sqrt{1-\rho^2}r}\cdot\int_{r_t}^r\frac{1}{r_1}e^{-\frac{1}{2(1-\rho^2)}\left[\left(\frac{\ln r-\mu}{\sigma}\right)^2+\left(\frac{\ln r_1-\mu}{\sigma}\right)^2-2\rho\left(\frac{\ln r-\mu}{\sigma}\right)\left(\frac{\ln r_1-\mu}{\sigma}\right)\right]}dr_1+$$

$$+2\frac{1}{2\pi\sigma^2\sqrt{1-\rho^2}r}\left(\frac{1}{2}+erf\left(\frac{\ln r_t-\mu}{\sigma\sqrt{2}}\right)\right)\cdot$$

$$\cdot\int_{r_t}^r\frac{1}{r_1}e^{-\frac{1}{2(1-\rho^2)}\left[\left(\frac{\ln r-\mu}{\sigma}\right)^2+\left(\frac{\ln r_1-\mu}{\sigma}\right)^2-2\rho\left(\frac{\ln r-\mu}{\sigma}\right)\left(\frac{\ln r_1-\mu}{\sigma}\right)\right]}dr_1+$$

$$+\frac{1}{\sqrt{2\pi}\sigma r}e^{-\frac{(\ln r-\mu)^2}{2\sigma^2}}\left(\frac{1}{2}+\frac{1}{2}erf\left(\frac{\ln r-\mu}{\sigma\sqrt{2}}\right)\right)\cdot$$

$$\cdot\left(\frac{1}{2}+erf\left(\frac{\ln r_t-(\mu+\rho(\ln r-\mu))}{\sigma\sqrt{1-\rho^2}\sqrt{2}}\right)\right)+$$

$$+\frac{1}{\sqrt{2\pi}\sigma r}e^{-\frac{(\ln r-\mu)^2}{2\sigma^2}}\cdot\int_{r_t}^r\frac{1}{\sqrt{2\pi}\sigma r_1}e^{-\frac{(\ln r_1-\mu)^2}{2\sigma^2}}\left(\frac{1}{2}+erf\left(\frac{\ln r_t-(\mu+\rho(\ln r_1-\mu))}{\sigma\sqrt{1-\rho^2}\sqrt{2}}\right)\right)dr_1+$$

$$+2\frac{1}{\sqrt{2\pi}\sigma r}e^{-\frac{(\ln r-\mu)^2}{2\sigma^2}}\left(\frac{1}{2}+erf\left(\frac{\ln r_t-(\mu+\rho(\ln r-\mu))}{\sigma\sqrt{1-\rho^2}\sqrt{2}}\right)\right)\cdot$$

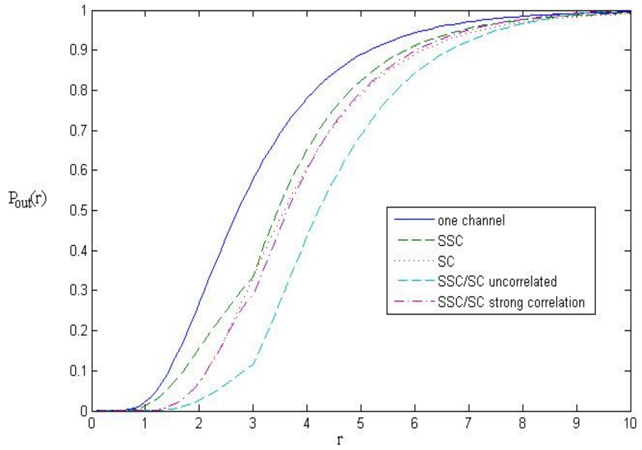
$$\cdot\int_{r_t}^r\frac{1}{\sqrt{2\pi}\sigma r_1}e^{-\frac{(\ln r_1-\mu)^2}{2\sigma^2}}\left(\frac{1}{2}+erf\left(\frac{\ln r_t-(\mu+\rho(\ln r_1-\mu))}{\sigma\sqrt{1-\rho^2}\sqrt{2}}\right)\right)dr_1 \tag{5.3.2}$$

Izrazi za gustinu raspodele verovatnoće su dobijeni u obliku jednostrukog integrala i mogu biti upotrebljeni za proračun ostalih karakteristika sistema.

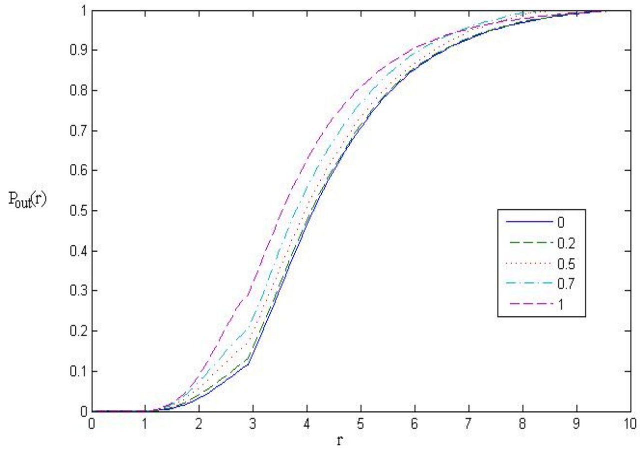
Verovatnoća otkaza se dobija na osnovu (5.1.6-7) i (5.3.1-2).

Verovatnoće otkaza za različite tipove kombinera u prisustvu log-normalnog fedinga za jednokanalni prijemnik, SSC i SC prijemnike u jednom trenutku vremena i SSC/SC prijemnik u 2 trenutka vremena u slučajevima bez korelacije i sa veoma jakom korelacijom na ulazima u kombiner su prikazane na slici 5.3.1. familije kriva za. Može se zaključiti da SSC/SC kombiner kao i u slučaju Rayleigh-jevog fedinga ima značajno bolje performanse za slučaj bez korelacije, a za slučaj sa jakom korelacijom, $\rho=1$, *SSC/SC* kombiner za $r<r_T$ prati rezultate za SC kombiner u jednom trenutku vremena, a u ostalom delu za SSC kombiner u jednom trenutku vremena.

Kada se analiziraju verovatnoće otkaza za SSC/SC kombinere u 2 trenutka vremena koje su prikazane na slici 5.2.2. takođe se kao za slučaj Rayleigh-jevog fedinga jasno uočava da se benefiti upotrebe ove vrste kombinera povećavaju sa smanjenjem korelacije između ulaznih signala.



Slika 5.3.1. Verovatnoće otkaza za različite tipove kombinera u prisustvu log-normalnog fedinga za parametre: $\mu=1$, $\sigma=0.5$, $\rho=0;1$



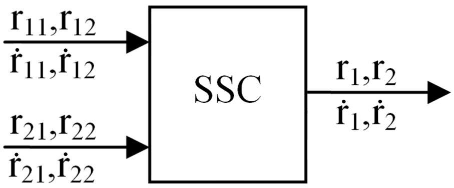
Slika 5.3.2. Verovatnoće otkaza za SSC/SC kombiner u dva trenutka vremena za različite vrednosti korelacije u prisustvu log-normalnog fedinga za parametre: $\mu = 1$, $\sigma = 0.5$, $\rho = 0;1$

6 Karakteristike drugog reda SSC/SC kombinera

Karakteristike drugog reda SSC/SC kombinera u dva trenutka vremena su važne za analizu rada složenih kombinera. Na osnovu rezultata za združene gustine raspodele verovatnoće signala i izvoda signala na izlazima iz SSC kombinera u dva trenutka vremena i izraza za združenu gustinu raspodele verovatnoće signala na izlazu, dobijaju se vrednosti za srednju učestanost preseka nivoa, a upotrebom srednje učestanosti preseka nivoa i verovatnoće otkaza može se odrediti srednje vreme trajanja otkaza.

6.1 Model sistema u dva trenutka vremena

U ovom poglavlju se razmatraju karakteristike drugog reda SSC/SC kombinera sa dve grane u dva trenutka vremena. Model sistema je prikazan na slici 6.1.1. Signali na ulazima su r_{11} i r_{21} u prvom trenutku vremena, a r_{12} i r_{22} u drugom trenutku vremena. Signali na izlazu iz SSC kombinera su r_1 i r_2. Izvodi signala na ulazima su $\dot{r}_{11}$ i $\dot{r}_{21}$ u prvom trenutku vremena, a $\dot{r}_{12}$ i $\dot{r}_{22}$ u drugom trenutku vremena. Izvodi signala na izlazu iz SSC kombinera su $\dot{r}_1$ i $\dot{r}_2$. Signal na izlazu iz složenog kombinerea je r, a njegov izvod $\dot{r}$. Verovatnoća da kombiner prvo razmatra signal na prvoj grani je P_1, a na drugoj je P_2.



Slika 6.1.1. Model SSC/SC kombinera sa dva ulaza u dva trenutka vremena sa izvodima signala

Združena gustina raspodele verovatnoće signala i izvoda signala na izlazu iz SC kombinera je:

$$p_{r\dot{r}}(r,\dot{r}) = p_{r_1}(\dot{r})\int_0^r p_{r_1r_2}(r,r_2)dr_2 + p_{r_2}(\dot{r})\int_0^r p_{r_1r_2}(r_1,r)dr_1 \qquad (6.1.1)$$

Združena gustina raspodele verovatnoće signala i izvoda signala na izlazu iz SSC/SC kombinera se dobija na osnovu združenih gustina raspodela verovatnoća signala na izlazima iz SSC kombinera u dva trenutka vremena i raspodela njihovih izvoda, zavisno od oblasti u kojoj se signali nalaze:

Za slučaj $r<r_T$ $(r_1<r_T,\ r_2<r_T)$

$$p_{r\dot{r}}(r,\dot{r}) = p_{r_1}(\dot{r})\int_0^r p_{r_1r_2}(r,r_2)dr_2 + p_{r_2}(\dot{r})\int_0^r p_{r_1r_2}(r_1,r)dr_1 \qquad (6.1.2)$$

Za slučaj $r\geq r_T$ $(r_1 \geq r_T,\ r_2 < r_T)$

$$p_{r\dot{r}}^{\,1}(r,\dot{r}) = p_{r_1}(\dot{r})\int_0^{r_T} p_{r_1r_2}(r,r_2)dr_2 + p_{r_2}(\dot{r})\int_{r_T}^r p_{r_1r_2}(r_1,r)dr_1 \qquad (6.1.3)$$

Za slučaj $r\geq r_T$ $(r_1 \geq r_T,\ r_2 < r_T)$

$$p_{r\dot{r}}^{\,2}(r,\dot{r}) = p_{r_1}(\dot{r})\int_{r_T}^{r} p_{r_1r_2}(r,r_2)dr_2 + p_{r_2}(\dot{r})\int_0^{r_T} p_{r_1r_2}(r_1,r)dr_1 \qquad (6.1.4)$$

Za slučaj $r\geq r_T$ $(r_1 \geq r_T,\ r_2 \geq r_T)$

$$p_{r\dot{r}}^{\,3}(r,\dot{r}) = p_{r_1}(\dot{r})\int_{r_T}^{r} p_{r_1r_2}(r,r_2)dr_2 + p_{r_2}(\dot{r})\int_{r_T}^{r} p_{r_1r_2}(r_1,r)dr_1 \qquad (6.1.5)$$

Ukupna združena gustina raspodele verovatnoće signala i izvoda signala na izlazu, za $r\geq r_T$ je:

$$p_{r\dot{r}}(r,\dot{r}) = p_{r\dot{r}}^{\,1}(r,\dot{r}) + p_{r\dot{r}}^{\,2}(r,\dot{r}) + p_{r\dot{r}}^{\,3}(r,\dot{r}) \qquad (6.1.6)$$

6.2 Karakteristike drugog reda SSC/SC kombinera u dva trenutka vremena u prisustvu Rice-ovog fedinga

Združena gustina raspodele verovatnoće signala i izvoda signala na izlazu iz SSC/SC kombinera u prisustvu Rice-ovog fedinga se dobija na oslovu gustina raspodela verovatnoća izvoda signala na izlazima iz SSC kombinera u dva trenutka vremena (4.5.2-3) i izraza (6.1.2-6).

Za slučaj $r<r_T$ $(r_1<r_T,\ r_2<r_T)$

$$
\begin{aligned}
p_{r\dot r}(r,\dot r) = \Bigg[& P_1\frac{1}{\sqrt{2\pi}\dot\sigma_1}e^{-\frac{\dot r_1^{\,2}}{2\dot\sigma_1^{\,2}}} + P_2\frac{1}{\sqrt{2\pi}\dot\sigma_2}e^{-\frac{\dot r_1^{\,2}}{2\dot\sigma_2^{\,2}}} + \\
& +\left(P_2\left[1-Q_1\left(\frac{A_2}{\sigma_2},\frac{r_T}{\sigma_2}\right)\right]-P_1\left[1-Q_1\left(\frac{A_1}{\sigma_1},\frac{r_T}{\sigma_1}\right)\right]\right)\frac{1}{\sqrt{2\pi}\dot\sigma_1}e^{-\frac{\dot r_1^{\,2}}{2\dot\sigma_1^{\,2}}} + \\
& +\left(P_1\left[1-Q_1\left(\frac{A_1}{\sigma_1},\frac{r_T}{\sigma_1}\right)\right]-P_2\left[1-Q_1\left(\frac{A_2}{\sigma_2},\frac{r_T}{\sigma_2}\right)\right]\right)\frac{1}{\sqrt{2\pi}\dot\sigma_2}e^{-\frac{\dot r_1^{\,2}}{2\dot\sigma_2^{\,2}}}\Bigg]\cdot \\
& \cdot\int_0^r\left[P_1D_2(r)D_1(r_2)+P_2D_1(r)D_2(r_2)\right]dr_2 + \\
& +\Bigg[P_1\left[1-Q_1\left(\frac{A_1}{\sigma_1},\frac{r_T}{\sigma_1}\right)\right]\left[1-Q_1\left(\frac{A_2}{\sigma_2},\frac{r_T}{\sigma_2}\right)\right]\frac{1}{\sqrt{2\pi}\dot\sigma_1}e^{-\frac{\dot r_2^{\,2}}{2\dot\sigma_1^{\,2}}} + \\
& +P_2\left[1-Q_1\left(\frac{A_1}{\sigma_1},\frac{r_T}{\sigma_1}\right)\right]\left[1-Q_1\left(\frac{A_2}{\sigma_2},\frac{r_T}{\sigma_2}\right)\right]\frac{1}{\sqrt{2\pi}\dot\sigma_2}e^{-\frac{\dot r_2^{\,2}}{2\dot\sigma_2^{\,2}}} + \\
& +P_1B_1(r_T)\frac{1}{\sqrt{2\pi}\dot\sigma_2}e^{-\frac{\dot r_2^{\,2}}{2\dot\sigma_2^{\,2}}}+P_2B_2(r_T)\frac{1}{\sqrt{2\pi}\dot\sigma_1}e^{-\frac{\dot r_2^{\,2}}{2\dot\sigma_1^{\,2}}} + \\
& +P_1\left[1-Q_1\left(\frac{A_1}{\sigma_1},\frac{r_T}{\sigma_1}\right)\right]Q_1\left(\frac{A_2}{\sigma_2},\frac{r_T}{\sigma_2}\right)\frac{1}{\sqrt{2\pi}\dot\sigma_2}e^{-\frac{\dot r_2^{\,2}}{2\dot\sigma_2^{\,2}}} + \\
& +P_2\left[1-Q_1\left(\frac{A_2}{\sigma_2},\frac{r_T}{\sigma_2}\right)\right]Q_1\left(\frac{A_1}{\sigma_1},\frac{r_T}{\sigma_1}\right)\frac{1}{\sqrt{2\pi}\dot\sigma_1}e^{-\frac{\dot r_2^{\,2}}{2\dot\sigma_1^{\,2}}} + \\
& +P_1C_1(r_T)\frac{1}{\sqrt{2\pi}\dot\sigma_1}e^{-\frac{\dot r_2^{\,2}}{2\dot\sigma_1^{\,2}}}+P_2C_2(r_T)\frac{1}{\sqrt{2\pi}\dot\sigma_2}e^{-\frac{\dot r_2^{\,2}}{2\dot\sigma_2^{\,2}}}\Bigg]\cdot \\
& \cdot\int_0^r\left[P_1D_2(r_1)D_1(r)+P_2D_1(r_1)D_2(r)\right]dr_1
\end{aligned}
\tag{6.2.1}
$$

Za slučaj $r \geq r_T$ $(r_1 \geq r_T,\ r_2 < r_T,\ r_1 \geq r_T,\ r_2 \geq r_T,\ r_1 \geq r_T,\ r_2 \geq r_T)$

$$p_{r\dot{r}}(r,\dot{r}) = \left[P_1 \frac{1}{\sqrt{2\pi}\dot{\sigma}_1} e^{-\frac{\dot{r}_1^{\,2}}{2\dot{\sigma}_1^{\,2}}} + P_2 \frac{1}{\sqrt{2\pi}\dot{\sigma}_2} e^{-\frac{\dot{r}_1^{\,2}}{2\dot{\sigma}_2^{\,2}}} + \right.$$

$$+\left(P_2\left[1-Q_1\left(\frac{A_2}{\sigma_2},\frac{r_T}{\sigma_2}\right)\right] - P_1\left[1-Q_1\left(\frac{A_1}{\sigma_1},\frac{r_T}{\sigma_1}\right)\right]\right) \frac{1}{\sqrt{2\pi}\dot{\sigma}_1} e^{-\frac{\dot{r}_1^{\,2}}{2\dot{\sigma}_1^{\,2}}} +$$

$$\left. +\left(P_1\left[1-Q_1\left(\frac{A_1}{\sigma_1},\frac{r_T}{\sigma_1}\right)\right] - P_2\left[1-Q_1\left(\frac{A_2}{\sigma_2},\frac{r_T}{\sigma_2}\right)\right]\right) \frac{1}{\sqrt{2\pi}\dot{\sigma}_2} e^{-\frac{\dot{r}_1^{\,2}}{2\dot{\sigma}_2^{\,2}}} \right] \cdot$$

$$\left[\int_0^{r_T} \left[P_1 \frac{r_2}{\sigma_2^{\,2}} e^{-\frac{r_2^{\,2}+A_2^{\,2}}{2\sigma_2^{\,2}}} I_0\left(\frac{r_2 A_2}{\sigma_2^{\,2}}\right) D_1(r) + P_1 D_2(r) D_1(r_2) + P_2 \frac{r_2}{\sigma_1^{\,2}} e^{-\frac{r_2^{\,2}+A_1^{\,2}}{2\sigma_1^{\,2}}} I_0\left(\frac{r_2 A_1}{\sigma_1^{\,2}}\right) D_2(r) + P_2 D_1(r) D_2(r_2) \right] dr_2 + \right.$$

$$+\int_{r_T}^{r} \left[P_1\left(1-Q_1\left(A/\sigma_1, r_t/\sigma_1\right)\right) \cdot \frac{r r_2}{\sigma_2^{\,4}(1-\rho^2)} e^{-\frac{r^2+r_2^{\,2}+2A_2^{\,2}(1-\rho)}{2\sigma_2^{\,2}(1-\rho^2)}} \cdot \sum_{i=0}^{\infty} \varepsilon_i I_i\left(\frac{\rho r r_2}{\sigma_2^{\,2}(1-\rho^2)}\right) I_i\left(\frac{A_2 r}{\sigma_2^{\,2}(1+\rho)}\right) I_i\left(\frac{A_2 r_2}{\sigma_2^{\,2}(1+\rho)}\right) + \right.$$

$$+ P_1 D_2(r_1) D_1(r_2) + P_2\left(1-Q_1\left(A/\sigma_2, r_t/\sigma_2\right)\right) \cdot$$

$$\cdot \frac{r_1 r_2}{\sigma_1^{\,4}(1-\rho^2)} e^{-\frac{r_1^{\,2}+r_2^{\,2}+2A_1^{\,2}(1-\rho)}{2\sigma_1^{\,2}(1-\rho^2)}} \cdot \cdot \sum_{i=0}^{\infty} \varepsilon_i I_i\left(\frac{\rho r_1 r_2}{\sigma_1^{\,2}(1-\rho^2)}\right) I_i\left(\frac{A_1 r_1}{\sigma_1^{\,2}(1+\rho)}\right) I_i\left(\frac{A_1 r_2}{\sigma_1^{\,2}(1+\rho)}\right) +$$

$$\left. + P_2 D_1(r) D_2(r_2) \right] dr_2 \quad + \int_{r_T}^{r} \left[P_1 \frac{r_1 r_2}{\sigma_1^{\,4}(1-\rho^2)} e^{-\frac{r_1^{\,2}+r_2^{\,2}+2A_1^{\,2}(1-\rho)}{2\sigma_1^{\,2}(1-\rho^2)}} \cdot \right.$$

$$\cdot \sum_{i=0}^{\infty} \varepsilon_i I_i\left(\frac{\rho r_1 r_2}{\sigma_1^{\,2}(1-\rho^2)}\right) I_i\left(\frac{A_1 r_1}{\sigma_1^{\,2}(1+\rho)}\right) I_i\left(\frac{A_1 r_2}{\sigma_1^{\,2}(1+\rho)}\right) +$$

$$+ P_1\left(1-Q_1\left(A/\sigma_1, r_t/\sigma_1\right)\right) \cdot \frac{r_1 r_2}{\sigma_2^{\,4}(1-\rho^2)} e^{-\frac{r_1^{\,2}+r_2^{\,2}+2A_2^{\,2}(1-\rho)}{2\sigma_2^{\,2}(1-\rho^2)}} \cdot$$

$$\cdot \sum_{i=0}^{\infty} \varepsilon_i I_i\left(\frac{\rho r_1 r_2}{\sigma_2^{\,2}(1-\rho^2)}\right) I_i\left(\frac{A_2 r_1}{\sigma_2^{\,2}(1+\rho)}\right) I_i\left(\frac{A_2 r_2}{\sigma_2^{\,2}(1+\rho)}\right) +$$

$$+ P_1 \frac{r_2}{\sigma_2^{\,2}} e^{-\frac{r_2^{\,2}+A_2^{\,2}}{2\sigma_2^{\,2}}} I_0\left(\frac{r_2 A_2}{\sigma_2^{\,2}}\right) D_1(r_1) + P_1 D_2(r_1) D_1(r_2) +$$

$$+ P_2 \frac{r_1 r_2}{\sigma_2^{\,4}(1-\rho^2)} e^{-\frac{r_1^{\,2}+r_2^{\,2}+2A_2^{\,2}(1-\rho)}{2\sigma_2^{\,2}(1-\rho^2)}} \cdot$$

$$\cdot \sum_{i=0}^{\infty} \varepsilon_i I_i\left(\frac{\rho r_1 r_2}{\sigma_2^{\,2}(1-\rho^2)}\right) I_i\left(\frac{A_2 r_1}{\sigma_2^{\,2}(1+\rho)}\right) I_i\left(\frac{A_2 r_2}{\sigma_2^{\,2}(1+\rho)}\right) +$$

$$+ P_2\left(1-Q_1\left(A/\sigma_2, r_t/\sigma_2\right)\right) \cdot \frac{r_1 r_2}{\sigma_1^{\,4}(1-\rho^2)} e^{-\frac{r_1^{\,2}+r_2^{\,2}+2A_1^{\,2}(1-\rho)}{2\sigma_1^{\,2}(1-\rho^2)}} \cdot$$

$$\cdot \sum_{i=0}^{\infty} \varepsilon_i I_i\left(\frac{\rho r_1 r_2}{\sigma_1^{\,2}(1-\rho^2)}\right) I_i\left(\frac{A_1 r_1}{\sigma_1^{\,2}(1+\rho)}\right) I_i\left(\frac{A_1 r_2}{\sigma_1^{\,2}(1+\rho)}\right) +$$

$$\left. \left. + P_2 \frac{r_2}{\sigma_1^{\,2}} e^{-\frac{r_2^{\,2}+A_1^{\,2}}{2\sigma_1^{\,2}}} I_0\left(\frac{r_2 A_1}{\sigma_1^{\,2}}\right) D_2(r_1) + P_2 D_1(r_1) D_2(r_2) \right] dr_2 \right] +$$

$$+\left[P_1\left[1-Q_1\left(\frac{A_1}{\sigma_1},\frac{r_T}{\sigma_1}\right)\right]\left[1-Q_1\left(\frac{A_2}{\sigma_2},\frac{r_T}{\sigma_2}\right)\right]\frac{1}{\sqrt{2\pi}\dot{\sigma}_1}e^{-\frac{\dot{r}_2{}^2}{2\dot{\sigma}_1{}^2}}+\right.$$

$$+P_2\left[1-Q_1\left(\frac{A_1}{\sigma_1},\frac{r_T}{\sigma_1}\right)\right]\left[1-Q_1\left(\frac{A_2}{\sigma_2},\frac{r_T}{\sigma_2}\right)\right]\frac{1}{\sqrt{2\pi}\dot{\sigma}_2}e^{-\frac{\dot{r}_2{}^2}{2\dot{\sigma}_2{}^2}}+$$

$$+P_1B_1(r_T)\frac{1}{\sqrt{2\pi}\dot{\sigma}_2}e^{-\frac{\dot{r}_2{}^2}{2\dot{\sigma}_2{}^2}}+P_2B_2(r_T)\frac{1}{\sqrt{2\pi}\dot{\sigma}_1}e^{-\frac{\dot{r}_2{}^2}{2\dot{\sigma}_1{}^2}}+$$

$$+P_1\left[1-Q_1\left(\frac{A_1}{\sigma_1},\frac{r_T}{\sigma_1}\right)\right]Q_1\left(\frac{A_2}{\sigma_2},\frac{r_T}{\sigma_2}\right)\frac{1}{\sqrt{2\pi}\dot{\sigma}_2}e^{-\frac{\dot{r}_2{}^2}{2\dot{\sigma}_2{}^2}}+$$

$$+P_2\left[1-Q_1\left(\frac{A_2}{\sigma_2},\frac{r_T}{\sigma_2}\right)\right]Q_1\left(\frac{A_1}{\sigma_1},\frac{r_T}{\sigma_1}\right)\frac{1}{\sqrt{2\pi}\dot{\sigma}_1}e^{-\frac{\dot{r}_2{}^2}{2\dot{\sigma}_1{}^2}}+$$

$$\left.+P_1C_1(r_T)\frac{1}{\sqrt{2\pi}\dot{\sigma}_1}e^{-\frac{\dot{r}_2{}^2}{2\dot{\sigma}_1{}^2}}+P_2C_2(r_T)\frac{1}{\sqrt{2\pi}\dot{\sigma}_2}e^{-\frac{\dot{r}_2{}^2}{2\dot{\sigma}_2{}^2}}\right]\cdot$$

$$\cdot\left[\int_{r_T}^{r}\left[P_1\frac{r}{\sigma_2{}^2}e^{-\frac{r^2+A_2{}^2}{2\sigma_2{}^2}}I_0\left(\frac{rA_2}{\sigma_2{}^2}\right)D_1(r_1)+P_1D_2(r_1)D_1(r)+\right.\right.$$

$$\left.+P_2\frac{r}{\sigma_1{}^2}e^{-\frac{r_2{}^2+A_1{}^2}{2\sigma_1{}^2}}I_0\left(\frac{rA_1}{\sigma_1{}^2}\right)D_2(r_1)+P_2D_1(r_1)D_2(r)\right]dr_1+$$

$$+\int_0^{r_T}\left[P_1\left(1-Q_1\left(A/\sigma_1,r_t/\sigma_1\right)\right)\cdot\frac{r_1r}{\sigma_2{}^4(1-\rho^2)}e^{-\frac{r_1{}^2+r^2+2A_2{}^2(1-\rho)}{2\sigma_2{}^2(1-\rho^2)}}\cdot\right.$$

$$\cdot\sum_{i=0}^{\infty}\varepsilon_iI_i\left(\frac{\rho r_1r}{\sigma_2{}^2(1-\rho^2)}\right)I_i\left(\frac{A_2r_1}{\sigma_2{}^2(1+\rho)}\right)I_i\left(\frac{A_2r}{\sigma_2{}^2(1+\rho)}\right)+$$

$$+P_1D_2(r_1)D_1(r)+$$

$$+P_2\left(1-Q_1\left(A/\sigma_2,r_t/\sigma_2\right)\right)\cdot$$

$$\cdot\frac{r_1r}{\sigma_1{}^4(1-\rho^2)}e^{-\frac{r_1{}^2+r^2+2A_1{}^2(1-\rho)}{2\sigma_1{}^2(1-\rho^2)}}\cdot$$

$$\cdot\sum_{i=0}^{\infty}\varepsilon_iI_i\left(\frac{\rho r_1r}{\sigma_1{}^2(1-\rho^2)}\right)I_i\left(\frac{A_1r_1}{\sigma_1{}^2(1+\rho)}\right)I_i\left(\frac{A_1r}{\sigma_1{}^2(1+\rho)}\right)+$$

$$\left.+P_2D_1(r_1)D_2(r)\right]dr_1+$$

$$+\int_{r_T}^{r}\left[P_1\frac{r_1r_2}{\sigma_1{}^4(1-\rho^2)}e^{-\frac{r_1{}^2+r_2{}^2+2A_1{}^2(1-\rho)}{2\sigma_1{}^2(1-\rho^2)}}\cdot\right.$$

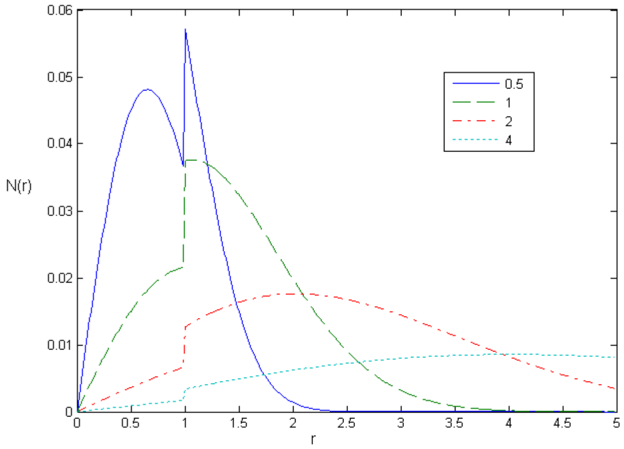
$$\cdot\sum_{i=0}^{\infty}\varepsilon_iI_i\left(\frac{\rho r_1r_2}{\sigma_1{}^2(1-\rho^2)}\right)I_i\left(\frac{A_1r_1}{\sigma_1{}^2(1+\rho)}\right)I_i\left(\frac{A_1r_2}{\sigma_1{}^2(1+\rho)}\right)+$$

$$+P_1\left(1-Q_1\left(A/\sigma_1,r_t/\sigma_1\right)\right)\cdot$$

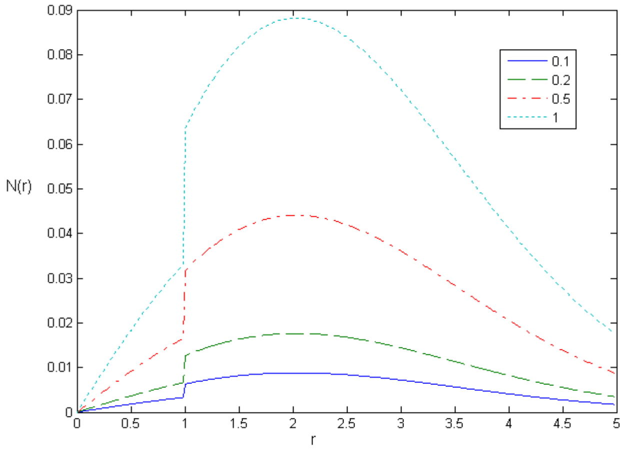
$$
\begin{aligned}
&\cdot \frac{r_1 r_2}{\sigma_2{}^4(1-\rho^2)} e^{-\frac{r_1{}^2+r_2{}^2+2A_2{}^2(1-\rho)}{2\sigma_2{}^2(1-\rho^2)}} \cdot \\
&\cdot \sum_{i=0}^{\infty} \varepsilon_i I_i\left(\frac{\rho r_1 r_2}{\sigma_2{}^2(1-\rho^2)}\right) I_i\left(\frac{A_2 r_1}{\sigma_2{}^2(1+\rho)}\right) I_i\left(\frac{A_2 r_2}{\sigma_2{}^2(1+\rho)}\right) + \\
&+ P_1 \frac{r_2}{\sigma_2{}^2} e^{-\frac{r_2{}^2+A_2{}^2}{2\sigma_2{}^2}} I_0\left(\frac{r_2 A_2}{\sigma_2{}^2}\right) D_1(r_1) + P_1 D_2(r_1) D_1(r_2) + \\
&+ P_2 \frac{r_1 r_2}{\sigma_2{}^4(1-\rho^2)} e^{-\frac{r_1{}^2+r_2{}^2+2A_2{}^2(1-\rho)}{2\sigma_2{}^2(1-\rho^2)}} \cdot \\
&\cdot \sum_{i=0}^{\infty} \varepsilon_i I_i\left(\frac{\rho r_1 r_2}{\sigma_2{}^2(1-\rho^2)}\right) I_i\left(\frac{A_2 r_1}{\sigma_2{}^2(1+\rho)}\right) I_i\left(\frac{A_2 r_2}{\sigma_2{}^2(1+\rho)}\right) + \\
&+ P_2\left(1 - Q_1\left(A/\sigma_2, r_t/\sigma_2\right)\right) \cdot \\
&\cdot \frac{r_1 r_2}{\sigma_1{}^4(1-\rho^2)} e^{-\frac{r_1{}^2+r_2{}^2+2A_1{}^2(1-\rho)}{2\sigma_1{}^2(1-\rho^2)}} \cdot \\
&\cdot \sum_{i=0}^{\infty} \varepsilon_i I_i\left(\frac{\rho r_1 r_2}{\sigma_1{}^2(1-\rho^2)}\right) I_i\left(\frac{A_1 r_1}{\sigma_1{}^2(1+\rho)}\right) I_i\left(\frac{A_1 r_2}{\sigma_1{}^2(1+\rho)}\right) + \\
&\left.\left. + P_2 \frac{r_2}{\sigma_1{}^2} e^{-\frac{r_2{}^2+A_1{}^2}{2\sigma_1{}^2}} I_0\left(\frac{r_2 A_1}{\sigma_1{}^2}\right) D_2(r_1) + P_2 D_1(r_1) D_2(r_2) \right] dr_1 \right]
\end{aligned}
\tag{6.2.2}
$$

Na osnovu izraza (6.2.1) i (6.2.2) se primenom u (2.2.5) i (2.2.6) dobijaju vrednosti za srednju učestanost preseka nivoa i srednje vreme trajanja otkaza.

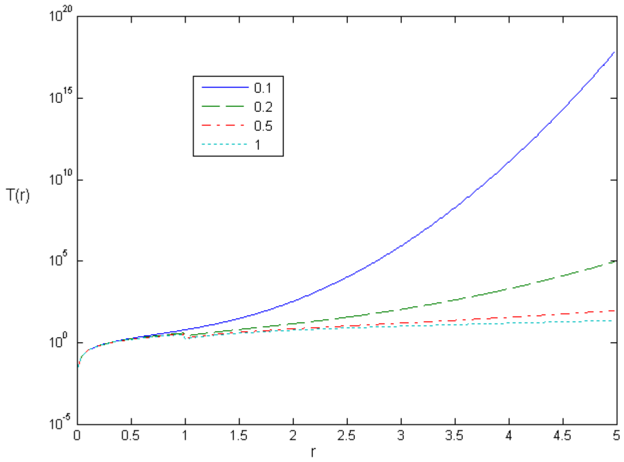
Na slikama 6.2.1 i 6.2.2 su prikazane vrednosti srednje učestanosti preseka nivoa za SSC/SC kombiner u dva trenutka vremena u prisustvu Rice-ovog fedinga za različite varijanse signala i njihovih izvoda, dok je srednje vreme trajanja otkaza predstavljeno na slikama 6.2.3 i 6.2.4.



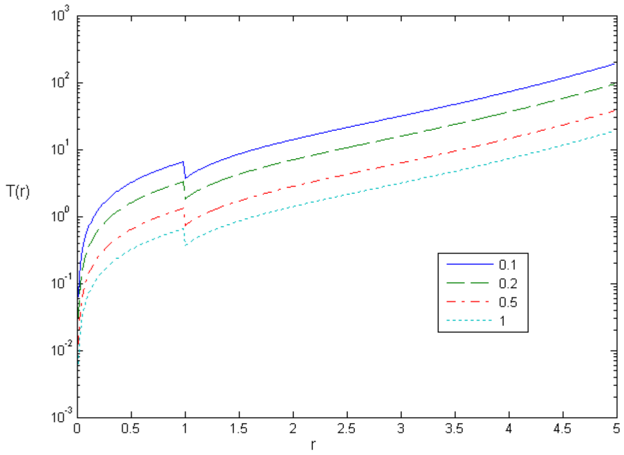
Slika 6.2.1. Srednja učestanost preseka nivoa za SSC/SC kombiner u dva trenutka vremena u prisustvu Rice-ovog fedinga za parametre: $r_T = 1$, $\sigma = 0.5; 1; 2; 4$, $A = 0.5$, $\dot{\sigma} = 0.2$



Slika 6.2.2. Srednja učestanost preseka nivoa za SSC/SC kombiner u dva trenutka vremena u prisustvu Rice-ovog fedinga za parametre: $r_T = 1$, $\sigma = 2$, $A = 0.5$, $\dot{\sigma} = 0.1;\ 0.2;\ 0.5;1$



Slika 6.2.3. Srednje vreme trajanje otkaza za SSC/SC kombiner u dva trenutka vremena u prisustvu Rice-ovog fedinga za parametre: $r_T = 1$, $\sigma = 0.5;\ 1;\ 2;4$, $A = 0.5$, $\dot{\sigma} = 0.2$



Slika 6.2.4. Srednje vreme trajanje otkaza za SSC/SC kombiner u dva trenutka vremena u prisustvu Rice-ovog fedinga za parametre: $r_T = 1$, $\sigma = 2$, $A = 0.5$, $\dot{\sigma} = 0.1;\ 0.2;\ 0.5;1$

7 Zaključak

U disertaciji su predstavljene karakteristike složenih kombinera u dva trenutka vremena u prisustvu fedinga koji je glavni uzrok degradacije performansi bežičnih komunikacionih sistema. Dat je model sistema za SSC/SC kombiner u dva trenutka vremena sa dve grane na ulazu u prvi stepen koji predstavlja SSC kombiner, a čiji izlazi u dva trenutka vremena čine ulaze u SC kombiner kao drugi stepen.

Prikazani su opšti izrazi za združenu gustinu raspodele verovatnoće signala na izlazu SSC kombinera sa dva ulaza u dva trenutka vremena, a za slučajeve prenosnih kanala u prisustvu fedinga koji se karakterišu Rayleigh-jevom, Nakagami-m, Rice-ovom, log-normalnom, Weibull-ovom i gamma raspodelem, izvedeni su izrazi u zatvorenom obliku, pogodni za korišćenje u daljoj analizi za dobijanje statističkih veličina kojima se opisuju karakteristike složenog kombinera.

Gustine raspodele verovatnoće i verovatnoće otkaza su dobijene za složeni SSC/SC kombiner, a na osnovu njih se mogu dobiti i momenti, veličina fedinga i verovatnoća greške po bitu.

Osim karakteristika prvog reda, analizirane su i karakteristike drugog reda kao što su srednja učestanost preseka nivoa i srednje trajanje otkaza, a na osnovu razvijenog matematičkog modela u kome su osim gustina raspodela verovatnoća signala uzete u obzir i raspodele izvoda signala.

Na primerima je ilustrovano da su karakteristike složenih SSC/SC kombinera bolje u odnosu na karakteristike klasičnih SC i SSC kombinera u jednom trenutku vremena, tako da se ovakav sistem može praktično primeniti u prijemnicima bežičnih digitalnih signala.

Rezultati dobijeni u ovoj disertaciji za karakteristike složenih SSC/SC kombinera u dva trenutka vremena u prisustvu fedinga se mogu iskoristi za dalji rad na analizi drugih tipova složenih kombinera u dva trenutka vremena, kao što su SSC/MRC ili SSC/EGC, kao i za prenosne sisteme u prisustvu različitih tipova fedinga koji nisu razmatarni u ovoj disertaciji.

8 Literatura

[1] M. K.Simon, M. S. Alouni, *Digital Communication over Fading Channels, 2nd ed.* Wiley, New Jersey, 2005.

[2] A. A. Abu-Dayya, N. C. Beaulieu, “Switched diversity on microcellular Ricean channels”, *IEEE Trans. on Vehicular Technology*, Vol. 43, No. 4, pp. 970–976, Nov. 1994.

[3] D. Tse, P. Viswanath, *Fundamentals of Wireless Communication*, Cambrige University Press, July 2005

[4] P. V. A. Goldsmith, *Wireless Communications*, Cambridge University Press, 2005.

[5] G. L. St¨uber, *Principles of Mobile Communications*, Norwell, MA: Kluwer Academic Publishers, 1996.

[6] S. O. Rice, “Statistical properties of a sine wave plus random noise”, *Bell Syst. Tech. J.*, Vol. 27, January 1948, pp. 109–157.

[7] M. K. Simon, Comments on “Infinite-Series Representations Associated With the Bivariate Rician Distribution and Their Applications”, *IEEE Trans. on Communications.*, Vol. 54, No 8, 25-28 Sept., 2005, pp. 2149 - 2153.

[8] N. C. Sagias, G. K. Karagiannidis, P. S. Bithas, P. T. Mathiopoulos, On the Correlated Weibull Fading Model and Its Applications, *Proc. Vehicular Techology Conference IEEE*, Vol. 4, Sept. 2005, pp. 2149-2153.

[9] http://mathworld.wolfram.com/LogNormalDistribution.html

[10] Suheyla Yerel, Adnan Konuk, “Bivariate lognormal distribution model of cutoff grade impurities: A case study of magnesite ore deposit”, *Scientific Research and Essay, v*ol.4 (12), Dec. 2009, pp. 1500-1504.

[11] http://mathworld.wolfram.com/GammaDistribution.html

[12] N. C. Sagias, D. A. Zogas, G. K. Karagiannidis, “Selection Diversity Receivers Over Nonidentical Weibull”, *IEEE Trans. on vehicular technology*, Vol. 54, No. 6, Nov. 2005

[13] N. C. Sagias, G. K. Karagiannidis, D. A. Zogas, P. T. Mathiopoulos, and G. S. Tombras, “Performance analysis of dual selection diversity over correlated Weibull fading channels”, *IEEE Trans. on Communications*, vol. 52, no. 7, pp. 1063-1067, July 2004.

[14] Y. C. Ko, M. S. Alouini and M. K. Simon, “Analysis and optimization of switched diversity systems”, *IEEE Trans. Veh. Technol.*, vol. 49, 2000, pp.1569-1574.

[15] Lin Yang, Mohamed-Slim Alouini, “Average Level Crossing Rate and Average Outage Duration of Switched Diversity Systems”, Global Telecommunications Conference, 2002. GLOBECOM '02. IEEE, Taipei, Taiwan, 17-21 Nov. 2002, Vol. 2, pp. 1420 - 1424, ISBN 0-7803-7632-3

[16] Lin Yang, Mohamed-Slim Alouini, “Average Level Crossing Rate and Average Outage Duration of Generalized Selection Combining”, IEEE Transactions on Communications, Vol. 51, No. 12, pp. 1063-1067, December 2003

[17] N. C.Sagias, D. A. Zogas., G. K. Karagiannidis, G. S Tombras., “Channel capacity and second order statistics in Weibull fading”, *IEEE Communication Letters*, Vol. 8, No. 6, pp. 377–379, Jun 2004.

[18] S. Primak, V. Kontorovich, “On the Second Order Statistics of Generalized Gamma Process”, *IEEE Trans. on communications,* Vol. 57, No. 4, April 2009.

[19] T. S. Rappaport, Wireless Communications: Principles and Practice. Upper Saddle River, NJ: PTR Prentice-Hall, 1996.

[20] S. S. Chakraborty, L. Yong, “Level Crossing Rate and Average Fade Duration of the Select-and-Hold Policy of Selection Diversity Combining in a Rayleigh Fading Channel”, *IEEE Communications letters*, Vol. 8, No. 6, June 2004.

[21] A. Mitić, M. Stefanović, "Second order statistics of the signal in Ricean-Lognormal fading channel with selection combining", *Facta Universitatis, Series: Elec. Energ.*, Vol. 20, No. 2, pp. 163-173, August 2007.

[22] M. Stefanović, D. Krstić, P. Nikolić, S. Jovković, D. M. Stefanović, “The Performances of the SSC Combiner Output Signal in the Presence of Nakagami-m Fading”, *International Journal of Communications*, Issue 1, Vol. 2, pp. 37-44, 2008, ISSN 1998-4480,

[23] P. Nikolić, M. Stefanović, D. Krstić, G. Stamenović, “The Joint Probability Density Function of the SSS Combiner Output in the Presence of Weibull Fading”, *XV International Symposium on Theoretical Electrical Engineering, ISTET '09*, Lübeck, Germany, June 22-24, 2009, ISBN 978-3-8007-3166-4

[24] D. Krstić, P. Nikolić, F. Destović, M. Stefanović, “The Joint Probability Density Function of the SSC Combiner Output Signal in the Presence of Log-Normal Fading”, *Electronics and Electrical Engineering*, *(Elektronika ir Elektrotechnika)*, No. 3 (109), pp. 11-16, 2011, ISSN 1392-1215

[25] D. Krstić, P. Nikolić, M. Matović, A. Matović, M. Stefanović, “The Performances of the SSC Combiner Output Signal in the Presence of Log-Normal Fading”, *WSEAS Transaction on Communications*, Issue 1, Vol. 8, pp. 31-40, January 2009, ISSN 1109-2742

[26] D. Krstić, M. Stefanović, P. Nikolić, Č. Stefanović, Z. Popović, “First and Second Order Statistical Characteristics of the SSC Combiner Output Signal in the Presence of Rice fading”, *International Journal On Advances in Telecommunications*, Vol. 2, No. 4, as the best in the session on AICT 2009. Conference, pp. 111-120, January 2009, ISSN 1942-2601

[27] D. Krstić, M. Stefanović, S. Jovković, P. Nikolić, “The joint probability density function of the SSC combiner with two inputs output signal in the presence of

Rice fading”, *International Scientific Conference UniTech ’06*, Gabrovo, Bulgaria, November 24-25, 2006, pp. I-275-282, ISBN 10:954-683-351-7

[28] P. Nikolić, M. Stefanović, D. Krstić, G. Stamenović, “The Joint Probability Density Function of the SSS Combiner Output in the Presence of Weibull Fading”, *XV International Symposium on Theoretical Electrical Engineering, ISTET '09*, Lübeck, Germany, June 22-24, 2009, ISBN 978-3-8007-3166-4

[29] D. Krstić, P. Nikolić, G. Stamenović, “Joint PDF for SSC Combiner Output Signal at Two Time Instants in Gamma Fading Channel“,*The 17th International Conference on Applied Electronics AE 2012,* Pilsen, Czech Republic, September 5-7, 2012, pp. 157-162, ISBN 978-80-261-0038-6

[30] D. Krstić, P. Nikolić, A. Stevanović, G. Stamenović, “Joint Probability Density Functions of SSC Receiver Output Signal at Two Time Instants and Their Derivatives Over Log-Normal Fading Channel“, *Buletinul Stiintific al Universitatii “Politehnica” din Timisoara, Romania, Seria Matematică-Fizică* = Scientific Bulletin of the “Politehnica” University of Timisoara, Romania, Transactions on Mathematics and Physics, ISSN 1224-6069, Volume 59 (73), Issue 1, No. 1, 2014, pp. 98-108,

[31] D. Krstić, P. Nikolić, G. Stamenović, M. Stefanović, “The joint probability density function of the SSC Combiner Output Signal at two Time Instants in the Presence of Hoyt Fading”, Proc. of the *The Seventh International Conference on Wireless and Mobile Communications, ICWMC 2011*, Luxembourg, June 19-24, pp. 204-210, ISBN 978-1-61208-008-6

[32] P. Nikolić, D. Krstić, M. Milić, M. Stefanović, “Performance Analysis of SSC/SC Combiner at Two Time Instants in The Presence of Rayleigh Fading”, *Frequenz,* Issue 11-12, Vol. 65, pp. 319–325, 2011, ISSN (Online) 2191-6349, ISSN (Print) 0016-1136

[33] M. Stefanović, P. Nikolić, D. Krstić, V. Doljak, “Outage probability of the SSC/SC combiner at two time instants in the presence of lognormal fading”, *Przeglad Elektrotechniczny (Electrical Review)*, Vol. 2012, No 3a, pp. 237-240, March 2012, ISSN 0033-2097,

[34] D. Krstić, P. Nikolić, D. Radenković, “The Performances of Complex SSC/MRC Combiner in the Presence of Rayleigh Fading”, *Network Protocols*

and Algorithms, ISSN 1943-3581, 2012, Vol. 4, No. 3, pp. 35-45, DOI:10.5296/npa.v4i3.2055, URL: http://dx.doi.org/10.5296/npa.v4i3.2055,

[35] D. Krstić, P. Nikolić, G. Stamenović, M. Stefanović, “The Bit Error Rate for Complex SSC/MRC Combiner at Two Time Instants in the Presence of Hoyt Fading”, *International Journal on Advances in Telecommunications*, Vol. 5, No. 1 & 2, pp. 69-78, 2012, ISSN 1942-2601

[36] D. Krstić, P. Nikolić, G. Stamenović, M. Stefanović “Bit error rate for SSC/MRC Combiner at Two Time Instants in The Presence of log-normal Fading”, *Facta Universitatis. Series Automatic Control and Robotics*, Vol.10, No 1, pp. 83–95, 2011, ISSN 1820-6417,

[37] D. Krstić, P. Nikolić, S. Panić, V. Doljak, ”The Bit Error Rate for Complex SSC/MRC Combiner in the Presence of Rayleigh Fading”, *The third International Conference on Information and Communication Systems ICICS ’12*, Irbid, Jordan, April 3-5, 2012

[38] D. Krstić, M. Stefanović, P. Nikolić, ”Bit Error Rate for Complex SSC/MRC Combiner in the Presence of Nakagami-m Fading”, *The Eighth Advanced International Conference on Telecommunications AICT 2012*, Stuttgart, Germany, May 27-June 1, 2012, pp. 75-80, ISBN 978-1-61208-199-1,

[39] P. Nikolić, D. Krstić, G. Stamenović, A. Stevanović, “The Performances of Complex SSC/MRC Combiner in the Presence of α-μ Fading”, *11th International Conference on Telecommunications in Modern Satellite, Cable and Broadcasting Services* – TELSIKS 2013*,* IEEE Catalog Number: CFP 13488-CDR, ISBN: 978-1-4799-0900-1, Niš, Serbia, Oktober 16-18, 2013, pp. 601-604.

[40] D. Krstić, P. Nikolić, G. Stamenović, “Probability Density Functions of Derivatives in Two Time Instants for SSC Combiner in Rician Fading Channel”, *The Eighth International Conference on Wireless and Mobile Communications, ICWMC 2012*, Venice, Italy, June 24-29, 2012, pp. 329-334, ISBN 978-1-61208-203-5

[41] D. Krstić, P. Nikolić, G. Stamenović, “PDFs of Time Derivatives at Two Time Moments in the Presence of Nakagami Fading”, *The 16th WSEAS International*

Conference on Communications (part of the 16th WSEAS CSCC'12 Multiconference), Kos Island, Greece, July 14-17, 2012, pp. 83-88, ISBN 978-1-61804-112-8

[42] P. Nikolić, D. Krstić, G. Stamenović, Z. Popović, "PDFs of Time Derivatives for SSC Combiner at Two Time Instants in Rayleigh Fading Channels", *The 8th IEEE, IET Int. Symposium on Communication Systems, Networks and Digital Signal Processing, CSNDSP 2012*, Poznan, Poland, July 18-20, ISBN 978-1-4577-1471-9, Print ISBN 978-1-4577-1472-6

[43] D. Krstić, P. Nikolić, "Second order statistics of SSC/SC combiner operating over Rician Fading Channel", *International Journal on Advances in Telecommunications*, ISSN: 1942-2601, vol. 7, nr. 1 & 2, year 2014, pp. 1/11

[44] P. Nikolić, *Uticaj fedinga i efekta senke na performanse digitalnih telekomunikacionih sistema, magistarska teza*, Univeryitet u Nišu, 2008.

[45] J.Cody, "An Overview of Software Development for Special Functions", *Lecture Notes in Mathematics*, 506, Numerical Analysis Dundee, G. A. Watson (ed.), Springer Verlag, Berlin, 1976.

[46] R.E. Ziemer, W.H. Tranter, *Principles of Communications: Systems, Modulation, and Noise*, 5th Edition, Wiley, New York, August 2001.

[47] J. G. Proakis, *Digital Communications*, 3rd ed. New York, NY: McGraw-Hill, 1995.

[48] Mohamed-Slim Alouini, "Switched Diversity Systems: Design, Performance, and Optimization", *Joint BEATS-Wireless IP Seminar*, June 5, 2003, Loen, Norway, Jun. 2003.

[49] M. S. Alouini, M. K. Simon, "Postdetection Switched Combining – A simple Diversity Scheme with Improved BER Performance", *IEEE Trans. on Commun.*, Vol. 51, No 9, 2003, pp 1591–1602

[50] Abu–Dayya A. A., Beaulieu N. C. Analysis of switched diversity systems on generalized – fading channels, *IEEE Trans. Commun.*, Vol. 42, 1994, pp 2959–2966.

[51] I. S. Gradshteyn and I. M. Ryzhik, *Table of Integrals, Series, and Products*, 5th ed. San Diego, CA: Academic Press, 1994.

[52] M. Nakagami, “The m-distribution- A general formula of intensity distribution of rapid fading”, *Statistical Methods in Radio Wave Propagation*, Oxford, U.K., Pergamon Press, 1960, pp. 3–36

[53] C. Tellambura, A. D. S. Jayalath, “Generation of Bivariate Rayleigh and Nakagami-m Fading Envelopes”, *IEEE Communication Letters*, vol. 4, No 5, May 2000, pp. 170–172.

[54] M. Z. Bocus, C. P. Dettmann, and J. P. Coon, “An approximation of the first order Marcum Q-function with application to network connectivity analysis”, IEEE *Communication Letters*, Vol. 17, No. 3, Mar. 2013, pp. 499-502

[55] http://mathworld.wolfram.com/Erf.html

[56] S. Yue, TBMJ Ouarda, B. Bobee, “A review of bivariate gamma distributions for hydrological application”, *J. Hydrol*. vol. 246, 2001, pp. 1-18

[57] E. Xekalaki, J. Panaretos and S. Psarakis, “A Predictive Model Evaluation and Selection Approach- The Correlated Gamma Ratio Distribution”, *Stochastic musings: perspectives from the pioneers of the late 20th century*, J. Panaretos, ed., Laurence Erlbaum, Publisher, USA, 2003, pp. 188-202

[58] P. Nikolić, D. Krstić, G. Stamenović, “Probability Density Functions of SSC Combiner Output Signal Derivatives at Two Time Instants in Weibull Fading Channel”, *1st WSEAS International Conference on Information Technology and Computer Networks ITCN ‘12*, Vienna, Austria, November 10-12, 2012, pp. 227-231, ISSN 1790-5109, ISBN 978-1-61804-134-0

[59] D. Krstić, P. Nikolić, G. Stamenović, “Probability Density Functions of Derivatives in Two Time Instants for SSC Combiner in Rician Fading Channel”, *The Eighth International Conference on Wireless and Mobile Communications, ICWMC 2012*, Venice, Italy, June 24-29, 2012, pp. 329-334, ISBN 978-1-61208-203-5

[60] P. Nikolić, Dragana Krstić, Aleksandar Stevanović, Goran Stamenović, „Probability Density Functions of SSC Combiner Output Signal Derivatives at Two Time Instants in the Presence of Log-normal Fading”, *11th International*

Conference on Applied Electromagnetics – ПЕС 2013, ISBN 978-86-6125-042-2, ISBN 978-86-6125-088-0, Niš, Serbia, September 01-04, 2013.

[61] D. B. Drajić, *Uvod u statističku teoriju telekomunikacija*, II izdanje, Akademska misao, Beograd, 2006.

[62] M. Patzold, U. Killat, F. Laue, "An extended Suzuki model for land mobile satellite channels and its statistical properties", *IEEE Trans. on Veh. Technol.*, Vol. 47, 1998, pp. 617 -630

Kratka biografija kandidata

Kandidat mr Petar Nikolić rođen je 29.03.1974. godine u Pirotu. Osnovnu i srednju školu završio je u Pirotu sa odličnim uspehom i kao nosilac diplome „Vuk Karadžić“. Za vreme školovanja u osnovnoj i srednjoj školi, učestvovao je na republičkim i saveznim takmičenjima iz matematike.

Nakon završene srednje škole, 1.10.1993. godine, upisao je Elektronski fakultet u Nišu, profil Elektronika i telekomunikacije, koji je završio sa prosečnom ocenom 9.13. Diplomski rad “Širokopojasna CDMA tehnika”, koji je radio pri Katedri za Telekomunikacije, odbranio je 23.03.2001. sa ocenom 10.

Od aprila 2001. god. radi u kompaniji Tigar Tyres iz Pirota. Posle završenih studija upisao je magistarske studije na Elektronskom fakultetu u Nišu iz oblasti Telekomunikacija. Položilo je sve ispite predviđene nastavnim planom postdiplomskih studija sa prosečnom ocenom 10. Magistrirao je 13.11.2008. odbranivši magistarsku tezu pod naslovom “Uticaj fedinga i efekta senke na performanse digitalnih telekomunikacionih sistema”.

U saradnji sa drugim autorima, napisao je 62 naučno-istraživačka rada, od kojih kojih su 12 objavljena u međunarodnim časopisima (3 sa SCI liste), 1 u domaćem časopisu, 39 radova su referisana na međunarodnim simpozijumima i konferencijama i štampana u zbornicima radova tih konferencija, dok je 10 referisano na stručnim konferencijama u našoj zemlji i štampano u odgovarajućim zbornicima radova.

Naučni radovi kandidata

Radovi objavljeni u časopisima međunarodnog značaja sa SCI liste (M23)

a.1. **Petar Nikolić**, Dragana Krstić, Miljana Milić, Mihajlo Stefanović, “Performance Analysis of SSC/SC Combiner at Two Time Instants in The Presence of Rayleigh Fading”, *Frequenz*, Issue 11-12, Vol. 65, pp. 319–325, 2011, ISSN (Online) 2191-6349, ISSN (Print) 0016-1136, http://www.degruyter.com/dg/viewarticle.fullcontentlink:pdfeventlink/$002fj$002ffreq.2011.65.issue-11-12$002ffreq.2011.048$002ffreq.2011.048.xml?format=INT&t:ac=j$002ffreq.2011.65.issue-11-12$002ffreq.2011.048$002ffreq.2011.048.xml (id:nikpetar@gmail.com, password: nikpetarfrequenz)

a.2. Dragana Krstić, **Petar Nikolić**, Fatih Destović, Mihajlo Stefanović, “The Joint Probability Density Function of the SSC Combiner Output Signal in the Presence of Log-Normal Fading”, *Electronics and Electrical Engineering*, *(Elektronika ir Elektrotechnika)*, No. 3 (109), pp. 11-16, 2011, ISSN 1392-1215, http://www.ee.ktu.lt/journal/2011/03/03__ISSN_1392-1215_The%20Joint%20Probability%20Density%20Function%20of%20the%20SSC%20Combiner%20Output%20Signal%20at%20two%20Time%20Instants%20in%20the%20Presence%20of%20Log%20Normal%20Fading.pdf

a.3. Mihajlo Stefanović, **Petar Nikolić**, Dragana Krstić, Vesad Doljak, “Outage probability of the SSC/SC combiner at two time instants in the presence of lognormal fading”,

Przeglad Elektrotechniczny (Electrical Review), Vol. 2012, No 3a, pp. 237-240, March 2012, ISSN 0033-2097,
http://pe.org.pl/articles/2012/3a/62.pdf

Radovi objavljeni u časopisima međunarodnog značaja van SCI liste (M24)

b.1. Dragana Krstić, **Petar Nikolić**, Dragan Radenković, “The Performances of Complex SSC/MRC Combiner in the Presence of Rayleigh Fading”, *Network Protocols and Algorithms*, ISSN 1943-3581, 2012, Vol. 4, No. 3, pp. 35-45, DOI:10.5296/npa.v4i3.2055, URL: http://dx.doi.org/10.5296/npa.v4i3.2055, http://www.macrothink.org/journal/index.php/npa/article/view/2055/2112

b.2. Dragana Krstić**, Petar Nikolić**, Aleksandar Stevanović, Goran Stamenović, „Joint Probability Density Functions of SSC Receiver Output Signal at Two Time Instants and Their Derivatives Over Log-Normal Fading Channel“, *Buletinul Stiintific al Universitatii “Politehnica” din Timisoara, Romania, Seria Matematică-Fizică* = Scientific Bulletin of the “Politehnica” University of Timisoara, Romania, Transactions on Mathematics and Physics, ISSN 1224-6069, Volume 59 (73), Issue 1, No. 1, 2014, pp. 98-108,
http://www.upt.ro/img/files/buletin_stiintific/mate/abstractBul1-2014.pdf

Radovi objavljeni u međunarodnim časopisima van SCI liste (M53)

c.1. Mihajlo Stefanović, Dragana S. Krstić, **Petar Nikolić**, Srdjan Jovković and Dušan M. Stefanović, “The Performances of the SSC Combiner Output Signal in the Presence of Nakagami-m Fading”, *International Journal of Communications*, Issue 1, Vol. 2, pp. 37-44, 2008, ISSN 1998-4480
http://www.naun.org/multimedia/NAUN/communications/c-32.pdf

c.2. Dragana Krstić, **Petar Nikolić**, Marija Matović, Ana Matović, Mihajlo Stefanović, “The Performances of the SSC Combiner Output Signal in the Presence of Log-Normal Fading”, *WSEAS Transaction on Communications*, Issue 1, Vol. 8, pp. 31-40, January 2009, ISSN 1109-2742
http://www.wseas.us/e-library/transactions/communications/2009/31-769.pdf

c.3. Dragana Krstić, Mihajlo Stefanović, **Petar Nikolić**, Časlav Stefanović, Zoran Popović, "First and Second Order Statistical Characteristics of the SSC Combiner Output Signal in the Presence of Rice fading", *International Journal On Advances in Telecommunications*, Vol. 2, No. 4, as the best in the session on AICT 2009. Conference, pp. 111-120, January 2009, ISSN 1942-2601
http://www.iariajournals.org/telecommunications/tele_v2_n4_2009_paged.pdf

c.4. **Petar Nikolić**, Dragana Krstić, Zoran Popović, Dušan Stefanović, Mihajlo Stefanović, "The Performance Analysis of MRC Combiner Output Signal in the Presence of Weibull Fading and Shadowing", *WSEAS Transactions On Communications*, Issue 1, Vol. 9, pp. 22-32, January 2010, ISSN 1109-2742
http://www.wseas.us/e-library/transactions/communications/2010/89-189.pdf

c.5. Dragana Krstić, **Petar Nikolić**, Mihajlo Stefanović, "The Outage Probability of the Satellite Telecommunication System in the Presence of Fading with Switch and Stay Combining on Satellite and Earth Station", *International Journal on Advances in Telecommunications*, Vol 4, No. 1&2, as the best in the session on ICWMC'10 Conference pp. 102-111, 2011, ISSN 1942-2601
http://www.iariajournals.org/telecommunications/tele_v4_n12_2011_paged.pdf

c.6. Dragana Krstić, **Petar Nikolić**, Goran Stamenović, Mihajlo Stefanović, "The Bit Error Rate for Complex SSC/MRC Combiner at Two Time Instants in the Presence of Hoyt Fading", *International Journal on Advances in Telecommunications*, Vol. 5, No. 1 & 2, pp. 69-78, 2012, ISSN 1942-2601
http://www.iariajournals.org/telecommunications/tele_v5_n12_2012_paged.pdf

c.7. Dragana Krstić, **Petar Nikolić**, „Second order statistics of SSC/SC combiner operating over Rician Fading Channel", *International Journal on Advances in Telecommunications*, ISSN: 1942-2601, vol. 7, nr. 1 & 2, year 2014, pp. 1/11, http://www.iariajournals.org/telecommunications/tele_v7_n12_2014_paged.pdf

Radovi objavljeni u domaćim časopisima (M51)

d.1. Dragana Krstić, **Petar Nikolić**, Goran Stamenović, Mihajlo Stefanović "Bit error rate for SSC/MRC Combiner at Two Time Instants in The Presence of log-normal Fading",

Facta Universitatis. Series Automatic Control and Robotics, Vol.10, No 1, pp. 83–95, 2011, ISSN 1820-6417, http://facta.junis.ni.ac.rs/acar/acar201101/acar2011-08.pdf

Radovi prezentovani na međunarodnim konferencijama (M33)

e.1. Dragana Krstić, Mihajlo Stefanović, Srđan Jovković, **Petar Nikolić**, “The joint probability density function of the SSC combiner with two inputs output signal in the presence of Rice fading”, *International Scientific Conference UniTech ’06*, Gabrovo, Bulgaria, November 24-25, 2006, pp. I-275-282, ISBN 10:954-683-351-7

e.2. **Petar Nikolić**, Dragana Krstić, Jelena Ristić, Vasko Todosijević, “Performances of MRC receivers for BPSK signals in the presence of log-normal and Nakagami-m fading”, *8th International Conference on Applied Electromagnetics – ПЕС 2007*, Niš, Serbia, September 3-5, 2007, ISBN 978-86-85195-47-0

e.3. **Petar Nikolić**, Dragana Krstić, Predrag Milačić, "Verovatnoća greške dual diverziti prijemnika pri prenosu BPSK signala u prisustvu log-normalnog i Nakagami-M fedinga", *Naučno-stručni Simpozijum Infoteh*, Jahorina, Bosna i Hercegovina, Mart 26-28, 2008, ISBN-99938-624-2-8

e.4. Dragana Krstić, **Petar Nikolić**, Dušan Stefanović, Ilija Temelkovski, “Level Crossing Rate of the SSC Combiner Output Signal in the Presence of Log-normal Fading”, *XLIII International Scientific Conference on Information, Communication and Energy Systems and Technologies ICEST 2008*, Niš, Serbia, June 25-27, 2008, ISBN 978-86-85195-61-7

e.5. Mihajlo Stefanović, Dragana Krstić, Petar Nikolić, Srdjan Jovković, Dušan Stefanović, “The Level Crossing Rate and Outage Probability of the SSC Combiner Output Signal in the Presence of Nakagami-m fading”, *The 12th WSEAS International Conference on Systems, (part of the 12th WSEAS CSCC Multiconference)*, Heraklion, Crete Island, Greece, July 22-24, 2008, pp. 395-400, ISSN 1790-2769, ISBN 978-960-6766-92-3

e.6. Dragana Krstić, Petar Nikolić, Marija Matović, Ana Matović, Mihajlo Stefanović, “The Outage Probability and Fade Duration of the SSC Combiner Output Signal in the Presence of Log-normal fading”, *The 12th WSEAS International Conference on Communications (part of the 12th WSEAS CSCC Multiconference)*, Heraklion, Crete

Island, Greece, July 23-25, 2008, pp. 321-326, ISSN 1790-5117, ISBN 978-960-6766-84-8

e.7. Dragana Krstić, **Petar Nikolić**, Marija Matović, Ana Matović, Mihajlo Stefanović, “The Joint Probability Density Function of the SSC Combiner Output Signal in the Presence of Nakagami-m fading”, *The Fourth International Conference on Wireless and Mobile Communications ICWMC 2008 and ICCGI 2008, (including the workshop ComP2P 2008)*, Athens/Vouliagmeni, Greece, July 27-August 1, 2008, pp. 409-416, ISBN 978-0-7695-3274-5

e.8. **Petar Nikolic**, Mihajlo C. Stefanovic, Dragana Krstic, Predrag Milacic, Srdjan Jovkovic, “Level Crossing Rate of the SSC Combiner Output Signal in the Presence of Rice Fading”, *17th International Electrotechnical and Computer Science Conference ERK 2008*, Portorož, Slovenia, September 29-Oktober 1, 2008, pp. 109-112

e.9. **Petar Nikolic**, Dragana Krstic, Zoran Milic, Danijela Arsic, „The Performances of MRC Receivers in the Presence of Log-Normal and Rice Fading”, *17th International Electrotechnical and Computer Science Conference ERK 2008*, Portorož, Slovenia, September 29-Oktober 1, 2008, pp. 113-116

e.10. Dragana Krstic, **Petar Nikolic**, Srdan Jovkovici, Mihailo Stefanovici; “Probability density function of M-ary FSK signal in the presence of Gaussian Noise, Intersymbol Interference and Log-Normal Shadowing”, *International Symposium on Electronics and Telecommunications ETC ’08*, Eighth Editions, Timisoara, September 25-26, 2008, Tom 5(67), Fascicola 2, pp. 252-255, http://www.tc.etc.upt.ro/bulletin/pdf/2008vol53_67no2.pdf

e.11. Dragana Krstić, **Petar Nikolić**, Goran Stamenović, Mihajlo Stefanović, “Probability Density Function of M-ary FSK Signal in the Presence of Gaussian Noise, Intersymbol Interference and Rice Fading”, *7th WSEAS International Conference on Data Networks, Communications, Computers (DNCOCO '08)*, Bucharest, Romania, November 7-9, 2008, ISSN 1790-5109, ISBN 978-960-474-020-8, pp. 58-62

e.12. Dragana Krstić, Goran Stamenović, **Petar Nikolić**, Mihajlo Stefanović, “Statistical Characteristics of Output Signal from Dual Diversity SC Combiner for Demodulation of BPSK Signals”, *International Scientific Conference UniTech ’08*, Gabrovo, Bulgaria, November 21–23, 2008, pp. I-224-227

e.13. Dragana Krstić, Mihajlo Stefanović, **Petar Nikolić**, Srdjan Jovković, Časlav Stefanović, “The Outage Probability and Fade Duration of the SSC Combiner Output Signal in the Presence of Rice fading”, *The Fifth Advanced International Conference on Telecommunications, AICT 2009*, Venice/Mestre, Italy, May 24-28, 2009, ISBN 978-0-7695-3611-8

e.14. **Petar Nikoli**ć, Mihajlo Stefanović, Dragana Krstić, Goran Stamenović, “The Joint Probability Density Function of the SSS Combiner Output in the Presence of Weibull Fading”, *XV International Symposium on Theoretical Electrical Engineering, ISTET '09*, Lübeck, Germany, June 22-24, 2009, ISBN 978-3-8007-3166-4

e.15. Mihajlo Stefanović, **Petar Nikolić**, Dragana Krstić, Goran Stamenović and Srdjan Milosavljević, “The Performances of Generalized Selection Combiner in the Presence of Generalized-K Fading Channels”, *XLIV International Scientific Conference on Information, Communication and Energy Systems and Technologies ICEST 2009*, Veliko Tarnovo, Bulgaria, June 25-27, 2009, Vol. 1, pp. 85-88

e.16. **Petar Nikolić**, Dragana Krstić, Goran Stamenović, Dušan Stefanović, Mihajlo Stefanović, “The Performance Analysis of MRC Combiner Output Signal in the Presence of Weibull and Log-normal Fading”, *13th WSEAS International Conference on Communications (part of 13th WSEAS Multiconference on Circuits, Systems, Communications and Computers)*, Rodos Island, Greece, July 23-25, 2009, ISSN 1790-5117, ISBN 978-960-474-098-7

e.17. Goran Stamenović, Dejan Rančić, Dragana Krstić, **Petar Nikolić**, Mihajlo Stefanović, “ Probability density function of M-ary FSK signal in the presence of Gaussian noise,intersymbol interference and generalized-K fading”, *9th International Conference on Applied Electromagnetics ПЕС 2009*, Niš, Serbia, August 31-September 2, 2009, ISBN 978-86-85195-84-6

e.18. Dragana Krstić, Mihajlo Stefanović, Goran Stamenović, **Petar Nikolić**, Časlav Stefanović, “The Performances of Generalized Selection Combiner in the Presence of Log-normal Fading”, *The Fifth International Conference on Wireless and Mobile Communications ICWMC 2009*, Cannes, French Riviera, France, August 23-29, 2009, pp. 352-358, ISBN 978-0-7695-3570-4

e.19. Dragana Krstić, **Petar Nikolić**, Goran Stamenović, Dušan Stefanović, „Performance Analysis of Generalized Selection Combiner in the Presence of Hoyt Fading“, *9th*

International Conference on Telecommunications in Modern Satellite, Cable and Broadcasting Services TELSIKS 2009, Niš, Serbia, Oktober 7-9, 2009, pp. 599-602, ISBN 978-1-4244-4383-3, ISBN 978-86-85195-81-5

e.20. Dragana Krstić, Dejan Rancić, **Petar Nikolić**, Zoran Popović, Goran Stamenović, Janko Aleksić, “Probability Density Function of the Satellite Signal in the Presence of Rayleigh Fading on Satellite and Earth Station”, *Naučno-stručni Simpozijum Infoteh*, Jahorina, Bosna i Hercegovina, Mart 17-19, 2010, Vol. 9, Ref. B-I-4, pp. 140-144, ISSN 99938-624-2-8,
http://www.infoteh.rs.ba/zbornik/2010/radovi/B-I/B-I-4.pdf

e.21. **Petar Nikolić**, Dragana Krstić, Ana Matović, Ivana Petrović, Ljupče Đorđević, “Probability density function of M-ary FSK signal in the presence of Gaussian noise, intersymbol interference and G fading”, *International conference of the Institute for Environment, Engineering, Economics and Applied Mathematics: International Conference on Circuits, Systems, Signals (CSS)*, Sliema, Malta, September 15-17, 2010, pp. 288-292, ISSN 1792-4324, ISBN 978-960-474-226-4

e.22. Dragana Krstić, **Petar Nikolić**, Marija Matović, Ana Matović, Mihajlo Stefanović, “The Satellite Telecommunication System Performances in the Presence of Nakagami Fading on Satellite and Earth Station”, *The Sixth International Conference on Wireless and Mobile Communications ICWMC 2010*, Valencia, Spain, September 20-25, 2010, pp. 170-176, ISBN 978-0-7695-4182-2

e.23. **Petar Nikolić**, Dragana Krstić, Mihajlo Stefanović, Stefan Panić, Fatih Destović, “Performance evaluation of MRC systems in the presence of Nakagami-m fading and shadowing”, *International Symposium on Electronics and Telecommunications ISETC 10*, Timisoara, Romania, November 11-12, 2010, pp. 289-293, ISBN 978-1-4244-8460-7

e.24. Dragana Krstić, **Petar Nikolić**, Goran Stamenović, Mihajlo Stefanović, “The joint probability density function of the SSC Combiner Output Signal at two Time Instants in the Presence of Hoyt Fading”, Proc. of the *The Seventh International Conference on Wireless and Mobile Communications, ICWMC 2011*, Luxembourg, June 19-24, pp. 204-210, ISBN 978-1-61208-008-6,

e.25. Dragana Krstić, **Petar Nikolić**, Stefan Panić, Vesad Doljak, ”The Bit Error Rate for Complex SSC/MRC Combiner in the Presence of Rayleigh Fading”, *The third*

International Conference on Information and Communication Systems ICICS '12, Irbid, Jordan, April 3-5, 2012

e.26. Dragana Krstić, Mihajlo Stefanović, **Petar Nikolić**, "Bit Error Rate for Complex SSC/MRC Combiner in the Presence of Nakagami-m Fading", *The Eighth Advanced International Conference on Telecommunications AICT 2012*, Stuttgart, Germany, May 27-June 1, 2012, pp. 75-80, ISBN 978-1-61208-199-1,

e.27. Dragana Krstić, **Petar Nikolić**, Goran Stamenović, "Probability Density Functions of Derivatives in Two Time Instants for SSC Combiner in Rician Fading Channel", *The Eighth International Conference on Wireless and Mobile Communications, ICWMC 2012*, Venice, Italy, June 24-29, 2012, pp. 329-334, ISBN 978-1-61208-203-5

e.28. Dragana Krstić, **Petar Nikolić**, Goran Stamenović, "PDFs of Time Derivatives at Two Time Moments in the Presence of Nakagami Fading", *The 16th WSEAS International Conference on Communications (part of the 16th WSEAS CSCC'12 Multiconference)*, Kos Island, Greece, July 14-17, 2012, pp. 83-88, ISBN 978-1-61804-112-8

e.29. **Petar Nikolić**, Dragana Krstić, Goran Stamenović, Zoran Popović, "PDFs of Time Derivatives for SSC Combiner at Two Time Instants in Rayleigh Fading Channels", *The 8th IEEE, IET Int. Symposium on Communication Systems, Networks and Digital Signal Processing, CSNDSP 2012*, Poznan, Poland, July 18-20, ISBN 978-1-4577-1471-9, Print ISBN 978-1-4577-1472-6,

e.30. Dragana Krstić, **Petar Nikolić**, Goran Stamenović, „Joint PDF for SSC Combiner Output Signal at Two Time Instants in Gamma Fading Channel",*The 17th International Conference on Applied Electronics AE 2012,* Pilsen, Czech Republic, September 5-7, 2012, pp. 157-162, ISBN 978-80-261-0038-6

e.31. **Petar Nikolić**, Dragana Krstić, Goran Stamenović, Dejan Rančić, "Second Order Statistics for SSC Receiver Over α-μ Fading Channels", *The 20th International Conference on Software, Telecommunications and Computer Networks SoftCOM 2012*, Split, Croatia, September 11-13, 2012, ISBN 978-953-290-035-4

e.32. **Petar Nikolić**, Dragana Krstić, Goran Stamenović, "Probability Density Functions of SSC Combiner Output Signal Derivatives at Two Time Instants in Weibull Fading Channel", *1st WSEAS International Conference on Information Technology and Computer Networks ITCN '12*, Vienna, Austria, November 10-12, 2012, pp. 227-231, ISSN 1790-5109, ISBN 978-1-61804-134-0

e.33. Dragana Krstić, **Petar Nikolić**, Goran Stamenović, Dejan Rančić "Second Order Statistics for SSC Receiver in the Presence of Hoyt Fading", *3rd European Conference of COMMUNICATIONS (ECCOM '12)*, Paris, France, December 2-4, 2012, pp. 299-304, ISBN: 978-1-61804-138-8,
http://www.naun.org/wseas/cms.action?id=861
http://www.wseas.us/e-library/conferences/2012/Paris/CICOCOM/CICOCOM-50.pdf

e.34. Dragana Krstić, **Petar Nikolić**, Goran Stamenović, "Performance Analysis of Complex Combiner at Two Time Instants in Weibull Fading Channel", *The Ninth Advanced International Conference on Telecommunications*, AICT 2013, ISSN: 2308-4030, ISBN: 978-1-61208-279-0, June 23 - 28, 2013 - Rome, Italy, pp. 33-37

e.35. Dragana Krstić, **Petar Nikolić**, Aleksandar Stevanović, Goran Stamenović, „The Performance Analysis of Complex SSC/MRC Combiner in Rice Fading Channel", The Ninth International Conference on Wireless and Mobile Communications, ICWMC 2013, ISBN: 978-1-61208-203-5, July 21-26, 2013, Nice, France, pp. 195-199.
Extended version of this paper is awarded for publication in *International Journal on Advances in Telecommunications*, ISSN: 1942-2601, year 2014, vol 7 nr 1&2.

e.36. **Petar Nikolić**, Dragana Krstić, Aleksandar Stevanović, Goran Stamenović, „Probability Density Functions of SSC Combiner Output Signal Derivatives at Two Time Instants in the Presence of Log-normal Fading", *11th International Conference on Applied Electromagnetics – ПЕС 2013*, ISBN 978-86-6125-042-2, ISBN 978-86-6125-088-0, Niš, Serbia, September 01-04, 2013.

e.37. Dragana Krstić, **Petar Nikolić**, Goran Stamenović, Aleksandar Stevanović, „Bit Error Rate for Complex SSC/MRC Combiner in Gamma Fading Channel", *Proceedings of the 18th International Conference on Applied Electronics - AE 2013*, IEEE Catalogue number CFP 1369A-PRT, ISBN 978-80-261-0166-6, ISSN 1803-7232, 10-12 September 2013, Pilsen, Czech Republic, pp. 149-152.

e.38. **Petar Nikolić**, Dragana Krstić, Goran Stamenović, Aleksandar Stevanović, "The Performances of Complex SSC/MRC Combiner in the Presence of α-μ Fading", *11th International Conference on Telecommunications in Modern Satellite, Cable and Broadcasting Services* – TELSIKS 2013, IEEE Catalog Number: CFP 13488-CDR, ISBN: 978-1-4799-0900-1, Niš, Serbia, Oktober 16-18, 2013, pp. 601-604.

e.39. **Petar Nikolić**, Dragana Krstić, Suad Suljević, Ivan Djurić, Ivana Dinić, "Second Order Statistics Analysis of Switch and Stay Combiner Affected by Weibull Fading", *12th International Conference on Applied Electromagnetics – PES 2015*, ISBN 978-86-6125-042-2, ISBN 978-86-6125-088-0, Aug.31 - Sep. 02, 2015, Niš, Serbia

Radovi prezentovani na domaćim konferencijama (M63)

f.1. Milan Denčić, **Petar Nikolić**, Tanja Denčić, "PCCS - Projects Cost Controle Software", *Zbornik radova YU INFO 2006 - Simpozijum o računarskim naukama i informacionim tehnologijama*, Kopaonik, Mart 6-10, 2006, ISBN 86-85525-01-2

f.2. **Petar Nikolić**, Zoran Milić, "SC i SSC dual diverziti sistemi u nekorelisanim kanalima u prisustvu log-normalnog i nakagami-M fedinga", *Zbornik radova L konferencije ETRAN 2006*, Beograd, Jun 6-8, 2006, sveska II, pp 66-69, ISBN 86-8059-58-2

f.3. Zoran Milić, **Petar Nikolić**, "Primena DDE standarda u komunikaciji industrijskih kontrolera i PC aplikacija", *Zbornik radova L konferencije ETRAN 2006*, Beograd, Jun 6-8, 2006, sveska I, pp 287-290, ISBN 86-8059-58-2

f.4. Dragana Krstić, Petar Spalević, **Petar Nikolić**, Jelena Ristić, "Prijemnik za koherentnu demodulaciju n-FSK signala u prisustvu Gausovog šuma", *Zbornik radova konferencije* XIV *Telekomunikacioni Forum TELFOR 2006,* Beograd, Novembar 21-23, 2006, pp. 309-312, ISBN 86-7466-275-7

f.5. **Petar Nikolić**, Dragana Krstić, Mihajlo Stefanović, Samir Koničanin, Zoran Milić, "Dual diverziti sistemi u prisustvu Log-normalnog i Rejlijevog fedinga", *Zbornik radova konferencije* XIV *Telekomunikacioni Forum TELFOR 2006,* Beograd, Novembar 21-23, 2006, pp. 301-304, ISBN 86-7466-275-7

f.6. Dragana Krstić, **Petar Nikolić**, Suad Šuljević, Srdjan Jovković, Vasko Todosijević, "MRC dual diverziti sistemi u prisustvu Rician-vog i log-normalnog fedinga", *Zbornik radova konferencije XV Telekomunikacioni Forum TELFOR 2007,* Beograd, Novembar 21-23, 2007, pp. 283-286, ISBN 978-86-7466-301-1

f.7. **Petar Nikolić**, Zoran Milić, Dragana Krstić, Petar Spalević, "Verovatnoća greške MRC prijemnika za BPSK signale u prisustvu log-normalnog i Rejlijevog fedinga", *Zbornik radova XIV Konferencije YUINFO '08*, Kopaonik, Mart 9-12, 2008, ISBN 978-86-85525-03-2, http://www.e-drustvo.org/proceedings/YuInfo2008/html/pdf/200.pdf

f.8. Dragana Krstić, **Petar Nikolić**, Mile Petrović, Ilija Temelkovski, Zoran Milić, ”Srednji broj osnih preseka izlaznog signala iz SSC kombinera u prisustvu Rejlijevog fedinga“, *Zbornik radova 52. konferencije ETRAN,* Palić, Jun 8-12, 2008, ISBN 978-86-80509-63-1

f.9. Dragana Krstić, **Petar Nikolić**, Goran Stamenović, and Mihajlo Stefanović, ”Probability Density Function of M-ary FSK Signal in the Presence of Gaussian Noise, Intersymbol Interference and Weibull Fading“, *Zbornik radova konferencije XVI Telekomunikacioni Forum TELFOR 2008*, Beograd, Novembar 25-27, 2008, pp. 340-343, ISBN 978-86-7466-337-0, http://2008.telfor.rs/files/radovi/04_05.pdf

f.10. Dragana Krstić, **Petar Nikolić**, Zoran Milić, Dragan Radenković, Mihajlo Stefanović, “Bit Error Rate of MRC Receiver for BPSK Signals in the Presence of G Fading”, *Zbornik radova konferencije IXX Telekomunikacioni Forum TELFOR 2011*, Beograd, Novembar 22-24, 2011, ISBN 978-1-4577-1498-6

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