

DSSS COMMUNICATION LINK  
EMPLOYING COMPLEX SPREADING  
SEQUENCES

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# DSSS COMMUNICATION LINK EMPLOYING COMPLEX SPREADING SEQUENCES

By

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# SUMMARY

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Master of Engineering (Electronics)

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The present explosion in digital communications and multi-user wireless cellular networks has urged a demand for more effective modulation methods, utilizing the available frequency spectrum more efficiently. To accommodate a large number of users sharing the same available frequency band, one requirement is the availability of large families of spreading sequences with excellent AC and CC properties. Another requirement is the availability of sets of orthogonal basis functions to extend capacity by exploiting all available degrees of freedom (e.g., temporal, frequency and spatial dimensions), or by employing orthogonal multi-code operation in parallel, such as used in the latest 3GPP and 3GPP2 Wide-band Code Division Multiple Access (WCDMA) modulation standards by employing sets of orthogonal Walsh codes to improve the overall data throughput capacity. The generic Direct Sequence Spread Spectrum (DSSS) transmitter developed in this dissertation has originally been designed and implemented to investigate the practicality and usefulness of complex spreading sequences, and secondly, to verify the concept of non-linearly interpolated root-of-unity (NLI-RU) filtering. It was found that both concepts have a large potential for application in point-to-point, and particularly micro-cellular Wireless Local Area Networks (WLANs) and Wireless-Local-Loop (WLL) environments. Since then, several novel concepts and subsystems have been added to the original system, some of which have been patented both locally and abroad, and are outlined below. Consequently, the ultimate goal of this research project was to apply the principles of the generic DSSS transmitter and receiver developed in this study in the implementation of a WLL radio-frequency (RF)-link, and particularly towards the establishment of affordable wireless multimedia services in rural areas. The extended coverage at exceptionally low power emission levels offered by the new design will be particularly useful in rural applications. The proposed WLL concept can for example also be utilized to add a unique mobility feature to for example existing Private Automatic Branch Exchanges (PABXs). The proposed system will in addition

offer superior teletraffic capacity compared to existing micro-cellular technologies, e.g., the Digital European Cordless Telephony (DECT) system, which has been considered by Telkom for employment in rural areas. The latter is a rather outdated interim standard offering much lower spectral efficiency and capacity than competitive CDMA-solutions, such as the concept analyzed in this dissertation, which is based on the use of unique large families of spectrally well confined (i.e., band-limited) constant envelope (CE) complex spreading sequences (CSS) with superior correlation properties. The CE characteristic of the new spreading sequences furthermore facilitates the design of systems with superior power efficiency and exceptionally robust performance characteristics (much less spectral re-growth) compared to existing 2G and 3G modulation standards, in the presence of non-linear power amplification. This feature allows for a system with larger coverage for a given performance level and limited peak power, or alternatively, longer battery life for a given maximum communication distance and performance level, within a specified fixed spreading bandwidth. In addition, the possibility to extend the concept to orthogonal multi-code operation provides for comparable capacity to present 3G modulation standards, while still preserving superior power efficiency characteristics in non-linear power amplification. Conventional spread spectrum communication systems employ binary spreading sequences, such as Gold or Kasami sequences. The practical implementation of such a system is relatively simple. The design and implementation of a spread-spectrum communication system employing complex spreading sequences is however considerably more complex and has not been previously presented, nor been implemented in hardware. The design of appropriate code lock loops for CSS has led to a unique design with 3dB performance advantage compared to similar loops designed for binary spreading sequences. The theoretical analysis and simulation of such a system will be presented, with the primary focus on an efficient hardware implementation of all new concepts proposed, in the form of a WLL RF-link demonstrator.

**Keywords:**

**Multi-Dimensional Direct Sequence Spread Spectrum (MD-DSSS), Families of Complex Spreading Sequences (CSS), Non-linearly Interpolated Root-of-Unity (NLI-RU) filtering, Complex Code Lock Loop (CCLL), Peak-to-Average Power Ratio (PAPR), PAPR Complementary Cumulative Distribution Function (CCDF), power and spectrally efficient modulation technique, DSSS Wireless RF Link.**

# OPSOMMING

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DSSS COMMUNICATION LINK EMPLOYING COMPLEX SPREADING SEQUENCES

deur

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Die huidige ontploffing in syferkommunikasie- en multi-gebruiker draadlose sellulêre dienste het die aanvraag na meer effektiewe modulasiemetodes, asook die meer effektiewe gebruik van frekwensiespektrum, sterk laat toeneem. Ten einde 'n groot aantal gelyktydige medegebruikers van dieselfde spektrum moontlik te maak, word die beskikbaarheid van groot families spreisekwensies met uitstekende outokorrelasie- (OK) en kruiskorrelasie- (KK) eienskappe benodig. 'n Verdere vereiste is die beskikbaarheid van stelle ortogonale basisfunksies waarmee die stelselkapasiteit uitgebrei kan word, deur die eksploitering van alle moontlike beskikbare vryheidsgrade (dws, temporale, frekwensie en ruimtelike dimensies), of deur die aanwending van veelvuldige ortogonale kodes (spreisekwensies) in parallel, soos byvoorbeeld in die jongste 3GPP en 3GPP2 Wyeband Kode-Divisie Multi-Toegang (WKDVT of 'WCDMA') modulasiestandaarde gebruik word, deur van stelle ortogonale Walsh codes gebruik te maak om die resultante data-deursettempo te verbeter. Die generiese DSSS-sender wat in hierdie verhandeling ontwikkel word, is oorspronklik ontwerp en geïmplementeer om eerstens die realiseerbaarheid en bruikbaarheid van komplekse spreisekwensies te ondersoek, en om tweedens die konsep van 'n nie-lineêre eenheidswortelfiltertegniek te verifieer en te evalueer. Dit is bevind dat beide konsepte 'n groot potensiaal vir aanwending in punt-tot-punt, en spesifiek mikro-sellulêre draadlose lokale-area netwerke (DLAN of 'WLAN') en draadlose lokale-lus (DLL of 'WLL') toepassings toon. Sederdien was die hoofogmerk van hierdie verhandeling om die generiese sender en ontvanger wat uit hierdie navorsings- en ontwikkelingsprogram voortgevloei het, in die implementering van een tipiese WLL RF-skakel aan te wend, en spesifiek vir die aanwending daarvan as syferkommunikasiemedium in plattelandse gebiede. Die besondere groot dekking teen buitengewone lae drywingsuitsetvlakke wat deur die nuwe ontwerp moontlik gemaak word, maak dit uiters geskik vir aanwending in hierdie gebiede. Dieselfde konsepte kan byvoorbeeld ook in 'WLL'-toepassings aangewend word, waardeur 'n mobiele dimensie aan bestaande stasies

private outomatiese taksentrales (POTS of 'PABXs') verleen kan word. Die voorgestelde stelsel sal ook verbeterde televerkeerskapasiteit in vergelyking met bestaande mikro-sellulêre tegnieke bied, soos bv die DECT-stelsel, wat deur Telkom oorweeg is vir gebruik in plattelandse gebiede. Laasgenoemde is tans 'n betreklik verouderde interim-standaard met baie laer spektrale effektiwiteit en kapasiteit as kompeterende CDMA-oplossings, as bv die modulاسie-konsep wat in hierdie verhandeling voorgestel word. Laasgenoemde is gebaseer op die gebruik van groot families unieke konstante-omhulling (KO) komplekse spreisekwensies (KSS) met goeie spektrale konsentrasie (dws, bandbeperk), sowel as met uitstekende korrelasie-eienskappe. Die KO-eienskappe van hierdie nuwe spreisekwensies maak verder die ontwerp van stelsels met verbeterde drywingseffektiwiteit en buitengewone robuuste werkverrigtingseienskappe moontlik, met veel minder spektrale groei in vergelyking met bestaande 2G en 3G modulاسiestandaarde in die teenwoordigheid van nie-lineêre drywingsversterking. Hierdie eienskappe maak stelsels met groter radiodekking vir 'n gegewe werkverrigtingspeil moontlik, of alternatiewelik, 'n langer batteryleeftyd vir 'n gegewe maksimum kommunikasie-afstand en werkpeil, binne 'n gespesifiseerde (vaste) spreibandwydte. Hierby bied die moontlikheid om die modulاسietegniek na veelvuldige kodes uit te brei, vergelykbare kapasiteit met huidige 3G modulاسiestandaarde, terwyl die superieure drywingseffektiwiteitskarakteristieke in die teenwoordigheid van nie-lineêre drywingsversterking gehandhaaf word. Die analise en ontwerp van konvensionele spreispektrum tegnieke wat van binêre spreisekwensies, soos Gold en Kasami, gebruik maak, is relatief eenvoudig. Die ontwerp en realisering van 'n spreispektrum-stelsel wat van komplekse spreisekwensies gebruik maak, is egter aansienlik kompleks, en is na die beste wete van die skrywer nog nie voorheen aangebied, of in hardware gerealiseer nie. Die ontwerp van geskikte kode-sluit-lusse (KSL) vir gebruik met komplekse spreisekwensies het gelei tot 'n unieke ontwerp met 'n 3 dB werkverrigtingsvoorsprong relatief tot soortgelyke lusse vir binêre spreisekwensies. Die teoretiese ontwerp, simulاسie en implementering van sodanige stelsel word in hierdie verhandeling aangebied, met die primêre fokus op die effektiewe en ekonomiese implementering van al die onderliggende substelsels wat die volledige prototipe WLL RF-skakel uitmaak.

**Sleutelwoorde:**

**Multi-Dimensionele Direkte-Sekwensie Sprei-Spektrum (MD-DSSS), Families Komplekse Spreisekwensies (KSS), Nie-Lineêre Geïnterpoleerde Eenheidswortel filters, Komplekse Kode-Sluit-Lus (KKSL), Piek-tot-Gemiddelde Drywingsverhouding (PGDV), Komplementêre Kumulatiewe Distribusie-Funksie (KKDF), drywings- en spektraal-effektiewe modulاسietegniek, DSSS Draadlose RF-verbinding.**

*To God Almighty  
for all the opportunities and His grace  
and  
to my loving wife, Estelle  
my late Father, my Mother, Brother, family  
and my family in law  
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