OFDM-Based

Spectrum Pooling:

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resources in during idle periods of licensed users. The basic idea is that licensed users do not need to be changed. Installed hardware can be operated like there is no other system present in the same frequency range.

This approach kills two birds with one stone

access to spectral Rental user obtain ranges they have not been. First , a short

At first, introduction to the general . ranges

structure of spectrum pooling transceiver and OFDM which utilized in rental user is given.

After that, specific tasks such as calculation

of detection and false alarm probabilities

,mutual interference in OFDM-based , and finally, combined spectrum pooling and based system are surveyed. A summary will close this article.

**2. The spectrum Pooling Scenario**

In this section , at first, we want to describe spectrum pooling idea and consideration that should be made regarding to the licensed user.



and adaptive bit loading for cognitive radio OFDM

*abstract* :**Public** **mobile radio spectrum is a scarce resource while wide spectral ranges are only rarely used. Here , we consider new strategy called Spectrum Pooling enabling public access to these new spectral ranges without sacrificing the transmission quality of the actual license owners. By temporarily leasing their spectrum during idle periods the license owners could tap new resources of revenue. In this paper, we want to review disparate aspect of spectrum pooling.**

*Keywords*—**Spectrum Pooling ,OFDM, ,Cyclostationary.**

**Introduction**

the success of future wireless resource will depend on the concepts and technology innovations in architecture and efficient utilization of spectral resources. The importance of ubiquitous wireless access to the internet has been constantly growing in last years. There will be a substantial need for more bandwidth as wireless application become more and more sophisticated. Old policies of spectrum licensing need to be rethought.

This article discuss a approach called spectrum pooling that enable public access to already frequency bands. The notion spectrum pooling was first mentioned in.

It basically shows the idea of merging spectral ranges from different owners into common pool. In this way, users can rent spectral

allocation vector is a binary representation of subcarrier that are allowed for or banned from the rental system usage. **3. Detection of a Spectral Access**

There is one question here :how to identify the idle spectral ranges that means how to prepare the allocation vector?

There are two methods for detection of licensed users. One of them is that using periodically energy detection and another is exploiting cyclo stationary properties of signals that, in further, each of them are described briefly. The reliable periodic detection of spectral access is a very crucial task in spectrum pooling since reliability is directly linked to the amount of additional interference faces when allowing secondly utilization to rental users. Two basic assumptions are to be made. First higher layer protocols such as MAP of the rental system must guarantee silence of all rental users during detection period . Thus , the only spectral power that remain in the air is that emitted by licensed users. Second ,as worst case consideration it is assumed that there is no line of sight between the transmitting licensed user and detecting rental user. this ensure in real situation with a potential line of sight the detection result can only get better than result in this situation. With application of central limit theorem, the received signal at rental user can be modeled as zero mean Gaussian process with an additive white Gaussian noise process originating from background noise of the mobile radio channel , and the thermal noise of the front-end baseband component. Hence, the statistic of the receive signal during the detection phase can be applied to detection algorithms derived from the Neyman-Pearson criterion. Low false alarm Probabilities are necessary in order to maintain the highest possible throughput in the rental system and the high false alarm probability would prevent idle spectral ranges of licensed system from being used , thus diminishing the efficiency of the rental system. In further section, we describe two cases said above .

A potential rental system needs to be highly flexible with respect to the spectral shape of the transmitted signal . This property is absolutely necessary in order to efficiency fill the spectral gaps the licensed users leave during their own idle periods. OFDM modulation is a suitable candidate for such a flexible rental system as it is possible to leave a set of subcarrier unused providing an adaptive transmit filter.

Note that it is necessary in an OFDM system that the coherence time of the channel be greater than duration of an OFDM symbol Ts it means that the channel can be considered constant during Ts . Another requirement is that the coherence bandwidth of channel be greater than subcarrier spacing ∆f . A major of advantage of the OFDM transmission schema is that possible to realize the parallel modulation by using IFFT operation. the main idea of OFDM-based spectrum pooling is to match the bandwidth of one sub band of the licensed system with integer multiple of the carrier spacing used in the rental user. In below, there is an example that represent this situation in fig(1) one licensed sub band is solved by set of four subcarrier of rental user .

OFDM has two advantages in a spectrum pooling. First, a set of subcarriers represented by their corresponding IFFT inputs can be fed

with zeros . If the rental user only uses lying in idle sub bands of licensed system ,spectral coexistence of both rental and licensed

system is possible at very low mutual interference. Second , an FFT operation is

required in order to invert OFDM modulation.

This FFT operation is necessary for the analysis the spectral activity of the licensed user ,it comes at no extra cost. The depicted

**a. collection and broadcast spectral measurement:**

One drawback of distributed approach is the enormous amount of measurement in the mobile terminals during the detection cycle that need to be transmitted to the access point . All of information must be gathered in access point for processing with

using logical OR operation .This is because it is sufficient that only mobile terminal detects

spectral access of the licensed in order to block the corresponding OFDM subcarrier.

However, all the allocation vectors cannot be transmitted in ordinary data frames. Another problem is that such data transmission can be error-prone as it is interfered by new licensed users. These new licensed users have accessed their sub band after last detection cycle . Hence, there could not be considered in actual allocation vector of the rental system, causing massive interference with the corresponding OFDM carrier of the rental system. The solution to this problem is using not the MAC layer but the physical layer for this signaling .A very nice method to realize this is the boosting protocol that is implemented after last detection. In further section, we describe this protocol in more details.[1]



Fig1: schematic example of an OFDM based spectrum pool .

**4. Efficient signaling of spectral resources in spectrum pooling system:**

One important task when implementing spectrum pooling is the periodic detection of idle sub bands of the licensed delivery . Here, we want to describe an approach where any associated mobile terminal of the rental system conducts its own detection . This detection is the first step in a whole protocol sequence .Having finished detection cycle, the result are then gathered at the access point .the received information can be processed by the access point which basically means that the individual binary (allocated/de allocated)detection results are logically combined by an OR operation. Thereafter, a common pool allocation vector which is mandatory for every mobile terminal in a last phase . However, if the collection of the detection results is realized by sending a MAC layer data packet for each mobile terminal, as mentioned before, signaling overhead will be very high as the number of mobile terminals can be as high as 250 in the considered wireless LAN systems. There is an approach where signaling is carried out in the physical layer saving a lot of transmission time .This technique is called boosting protocol is divided into two different phases .In the first phase, sub bands are signaled that are newly accessed since the last detection cycle. The second phase is dedicated to signaling sub bands that have become idle since the last detection cycle [2].

**5.Mutual Interference in OFDM-based spectrum pooling**

For explaining mutual interference, at first ,we should describe, briefly, details about interference to the licensed system and rental system ,then, counter measures to the mutual interference .

**a. Interference to the licensed system:**

The interference is caused by the side lobes of the OFDM signal . the transmit signal s(t) on each single carrier of the considered wireless standards is the rectangular NRZ signal . So , the power density spectrum (PDS) of s(t) is represented in this form:

Where A denotes the signal amplitude and Ts is the symbol duration which consists of the the sum of the useful duration Tu and guard interval Tg .i It is assumed that licensed user sub band are co-located with single sub carriers or sets of subcarriers. First, the case is considered that the bandwidth of one LS sub band is ∆f =1/Tu. ∆f is subcarrier spacing of the RS .the mean relative interference power to one LS sub band PR \_\_ L(n) is defined as:

Where PTOT is the total power emitted on one subcarrier and n represents the distance between the considered subcarrier and LS sub band in multiples of ∆f which is illustrated in fig (2).

**** Fig(2):PDS of single OFDM modulated carrier in IEEE 802.11a.

For n=1 with calculating (2) table (1) is attained. If bandwidth of the LU sub band is a multiple of ∆f , the total interference power of one subcarrier can be obtained by adding the values from this table.

table 1

**Interference to the rental system: B.**

The reception of an OFDM symbol is performed using N-FFT function.

This implies that received signal r(k) is windowed in time domain by a rectangular window function w(k) resulting in:

r°(k)=r(k)w(k) ,(3)

Hence, the Fourier transform X( of r°(k) is represented by a convolution of the Fourier transforms and of their respective time signals r(k) and w(k) . this yields :

If a rectangular window function is assumed, the PDS after N-FFT processing can be obtained by the following expected value of the periodogram:

*d*

Where is the PDS of r(k) that is smeared by convolution term in (5) . this smearing does not destroy orthogonality in a pure OFDM system but SP system face a superposition with the LU signal .the effect of (5) in LU signal is depicted in fig(3) that, in there, elliptically filtered white noise process was assumed as LU signal. The circles indicate the sampling point of the 64 N-FFT in our example. One thing can be seen in fig(3) the significant parts of the LU energy are scattered to adjacent FFT bins where they interfere with the corresponding symbols of the OFDM transmission . like(2) the mean relative interference power to one subcarrier of the RS PR---L(n) is defined. 

Fig(3):Impact of FFT processing on the PDS of the LU

**C. CONTERMEASUREMENT TO THE MUTUAL INTERFERENCE:**

One possible solution for overcoming the interference of the RS to LS is making the PDS in Fig(2) go down more rapidly by windowing the transmit signal of the OFDM symbol.

This makes the amplitude go smoothly to zero at the symbol boundaries . A commonly used window type is the raised cosine that is defined by:

Where β represent roll-off factor .the symbol time Ts is shorter than the total symbol duration (1+β)Ts because adjacent symbols are allowed to partially overlapped in the roll-off region. The time structure of the OFDM signal using g(t) as transmit filter is depicted in fig (4). It can be seen that the cyclic prefix must be extended in order to achieve the same resistance against ISI . Postfix needs to be longer than βTs to maintain orthogonality within the OFDM signal. Hence ,the drawback of interference reduction method is temporal extension of the symbol duration by the factor (1+β)Ts resulting in a reduced system throughput of the RS system. 

fig(4):structure of OFDM signal using a raised cosine transmit filter.

Fig(5) shows that the effect of β on the PDS of the RU signal .We show that side lobes are obviously attenuated. Here, we suppose that the bandwidth of one LS sub band matches one subcarrier spacing ∆f the first adjacent LS LS sub band is illustrated in fig(5) and we can calculate PDS like(2) . The result of this calculation only depend on β and number of the LS sub band and depicted in fig(5).the positive of raised cosine filter is stronger than regarding LS sub band that are further away from the considered RS subcarrier for n but unfortunately, the positive effect of raised cosine filter is small for n=1 even at very high β and the achievable interference reduction is 6 db in high β. So ,we conclude that raised cosine method is good but not enough for solving this problem and another method is necessary to develop.

 Fig(5): Impact of roll off factor on the PDS of the rental user signal. Fig(6): Interference power in different LU sub bands as a function of B.

Another method for reduction this case is the dynamically deactivation subcarrier lying adjacently to allocated LS sub bands and it provides flexible guard band as pointed out in fig(7).the number of subcarrier that is covered by one LS sub band is denoted by α while the number of deactivated adjacent sub carriers is described by β. The advantage of this method compared to raised cosine is both types of interference (i.e. LS to RS and RS to LS)is mitigated but sacrifice bandwidth and throughput of RS system. with combining two methods ,as mentioned above ,we can achieve that the power spectrum goes down to zero at frequency close to occupied spectrum more rapidly [3] .

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Fig (7):Deactivation of adjacent subcarriers provides dynamic guard bands between LS and RS.

**6. Calculation of detection and false alarm probabilities in spectrum pooling systems:**

In this section, we want to describe a calculation formula for the general case of an arbitrary measurement covariance matrix is derived.

Under the worst case assumption of a non line of sight between a LS and RS, the receive signal at the detecting RS can be considered zero-mean rotationally symmetrical complex Gaussian process according to the central limit theorem and noise in received signal is assumed to be white zero-mean and Gaussian . The resulting process is block wise transformed into the frequency domain by the immanently available FFT of the OFDM receiver .The consecutively arriving frequency samples corresponding to the useful signal of one LS sub band can be combined in a vector z, containing the real and imaginary parts x, y of the respective FFT bins .As a FFT is a linear operation ,it can be shown that z still has a normal distribution. Let n denote the number of FFT operation performed during a detection process and m is the width of an LS sub band in OFDM subcarriers and PDF of z can be written:

With:

Where Css represents the nonsingular covariance matrix of the time-frequency samples of the considered LS .

Where the diagonal elements ,namely ,are the mean receive power of the real and imaginary parts and the process noise is distributed according :

Where is just the mean noise power of the real and imaginary parts. As the LS signal is additively distributed by the noise process The pdf of the resulting samples can be calculated by convolution of fs(z) and fN(z) ,yielding the conditional PDFs:

The optimal detection rule that classifies whether or not a LU access has occurred in the considered sub band is based on the well known Neyman-Pearson criterion that maximizes the detection probability PD at a given false alarm probabilities PF at a given PD ,respectively . Applying this criterion yields

Where G𝔬 is the area contains all vectors z leading to the decision that an LU access has occurred .The optimal decision space G is obtained from the likelihood ratio:

Where the choice of determines PD. Finally, we can say PD into another form like this:

Where , , V=CSS+,

A=-(V)-1 and u can be obtained corresponding combining (9),(10),(11),(12) yields,

u= 2

calculating the corresponding eigen values and setting detection threshold u is required by AP(access point). After the RUs have transmitted their resulting false alarm probabilities to the AP ,n can be adapted in order to maximize the RS efficiency. The interesting problem of how to estimate the covariance matrices and how to adapt n within the resulting feedback loop in an optimal fashion and need to be further investigated[4]. . **7.Sychronization algorithm and preamble concepts for spectrum pooling systems:**

The OFDM as a modulation technique is very sensitive to phase noise , frequency offset and timing errors.Thecarrier phase is followed by the use of pilots and in SP system they are affected by narrow-band interference .So, the adaptive poisoning of the pilots avoiding collisions with narrow-bands interferers is an important task that is currently investigation. Here, we focus on frame and frequency synchronization based on preamble. If we want to apply mathematical models that are used in ordinary systems on SP, we will meet it with an obstacle. It is not always possible to transmit short training symbols. The reduction of the symbol duration to 1/4 of its original length implies that every forth carrier can potentially interfere with an LU. Furthermore, the suppression of subsets of carriers would destroy the temporal orthogonality of the short training symbols. Hence, the techniques are proposed by the standard are not applicable to SP and new methods need to be derived. We describe two methods for this purpose.

**A. Synchronization techniques for SP based on autocorrelation:**

The first approach we would like to present is the transition from short training symbols to fill length (80 samples)training symbols. Therefore, two identical sequenced training symbols are necessary that are not separated by a guard interval.

****fig(8):Preamble for the estimation ∆fc and frame start with long symbols**.**

fig(8) shows the typical structure of such a preamble , it consists of the three repeated symbols followed by a copy of the last samples of the last symbol. The symbols A,B,C are 80 samples long in the style of the IEEE802.11a symbol length.Where c' comprise 64 samples. The problem with this method is that some OFDM carriers encounter interference when the LUs access their sub bands. If the traffic volume in the LS rises, more and more OFDM carriers will be affected .Two functions have to fulfilled with the use of this correlator output. First, the reception valid preamble has to be detected. This could be done with a simple threshold stage at the output of correlator. Unfortunately, the correlation peak diminishes when the pool allocations(i.e. relative number of all OFDM carriers that are interfered with by LU access)rises and reliability of the preamble detection degrade.

secondly ,the exact start of the frame needs to be determined by finding correlation peak but if we compare two different pool allocations ,we see that high pool allocation causes the peak value of correlator is delayed and the effective length of the guard interval, which is necessary for maintaining the orthogonality, is shorten. Hence, error-free detection is impossible for high pool allocation.

**B**: **Synchronization techniques for SP based on cross-correlation and adaptive filtering :** Another solution is cross-correlating the received samples with preamble sequences stored in the receiver instead of auto correlating the received samples with a delay version .Figure(9) shows this situation :

fig(9): structure of the frame detector and frequency offset estimator The frame start estimation can be realized by finding the peak value of L:

Where x(k) is sequence that is stored in receiver. One possible way for reduction narrow band interference by LUs is that using adaptive filter that cuts out the OFDM carriers that are subject to interference by transmitting LU before the signal is fed into correlator as depicted in fig(10). This task is done by access point which gathers all the measured data and broadcasts the carrier allocation back to the stations. Some LUs disturb the synchronization of the RS even with a perfect periodic estimation of the carrier allocation in the access point when new LUs access their sub bands that were detected idle in the last detection period [5].



fig(10):frame detector with cross correlator and adaptive prefilter.

**8. On extraction channel allocation information in spectrum pooling:**

The use of OFDM based RS ,as proposed above, provides the required flexibility for the RS in terms of spectral occupation, since, OFDM makes it possible to adapt the number and the position of the modulated carrier according to the channel allocation information(CAI).The reliable extraction of the CAI is a key challenge for enabling the coexistence of two systems on the same frequency range. The extraction of CAI is performed at regular intervals, during so called silent period ,in which RS stops transmitting and performs energy measurement to detect the presence of the LS in the channel. While having the advantage of being simple , this approach exhibits two main problems:

The energy detection approach has a poor reaction speed, since no detection is possible between two silent periods, i.e. while the RS is transmitting .

Employing silent periods decreases the efficiency of the RS. The use of silent periods can be omitted by employing methods capable of detecting the presence of the LS even while the RS is transmitting in the same frequency sub band at the same time ,which requires distinguishing between the source of the detected energy. Exploiting the cyclo stationary characteristics of the license owner signal provides the necessary signal selectivity required for this task, assuming cyclic features of the RS and LS signals are different from each other ,which in usually the case, since, different wireless standards usually employ different signal structures and parameters , leading to different cyclostationary characteristics. In this section , we want to show an approach by examining a specific spectrum pooling example which has a GSM network as the LS and a wireless LAN system based on OFDM as the RS .this situation is depicted in fig(11) . 

Fig(11): spectrum pooling scenario under consideration.

Firstly , we define cyclostationary process then investigate the cyclostationary characteristics of OFDM based RS and GSM based LS signals. Finally , we demonstrate a detection process under this condition. A schematic of this situation is depicted in

fig (12).

Fig(12): A Typical channel occupation scenario.

**A**. **Preliminaries:**

A zero mean complex wide sense cyclostationary process x(t) is characterized by a time varying autocorrelation function Rxx(t,τ)=E{x(t) x\*(t+τ)}, which periodic in time t and can be represented as a Fourier series: and: ,(20)

is called the cyclic autocorrelation function (CAF) and the spectral correlation density (SCD) is defined as the Fourier transform of :

A useful modification of the CAF is called the conjugate cyclic autocorrelation function ,which is given:

and:

for non-cyclostationary signal , ,for which the conjugate and non-conjugate CAFs differ from zero is called a cycle frequency and the discrete set of the cycle frequencies Axx corresponding to Rxx(τ) and Axx\* corresponding to are referred to as the cycle spectrum and conjugate cycle spectrum, respectively. For communication signals, these cycle frequencies are typically related to signal specific parameter such as symbol or chip rate ,modulation index ,carrier frequency. The motivation behind this approach lies in discriminatory capability that use of cyclic statistics presents between the signal sources with disparate cycle spectra and cyclostationary characteristics . Let x(t) be a composite signal :

x(t)=), (24)

with suppose that is statistically independent of each other ,it can easily shown:

and

choosing α=αk≠0 so that only signal with the specific cycle frequency αk is sk(t) ,I .e . αk and αk , , we can written :

and

Hence , when multiple signals overlap in time and frequency domain ,their conjugate or non-conjugate CAF and SCD function do not overlap in the cycle frequency domain as long as the signals possess distinct cycle frequencies .Therefore, provided that the RS and LS signals exhibit disparate cycle spectra , the presence and absence of the cycle signature of the LS signal in the total received signal mix is a distinct feature that can be exploited for the detecting the CAI ,even if the RS is transmitting at the same time in the same frequency band. The transmission schema employed by the LS and cyclostationary statistics has to be known by the RS designer, which is reasonable assumption in the case that the licensed system is a commercial wireless network. **B. Cyclostationary Characteristic of the OFDM based RS signal:** In OFDM system ,the PSK or QAM modulated information symbols are transmitted over multicarrier in parallel. The baseband OFDM signal can be expressed like this:

it can be easily shown that the OFDM signal does not exhibit conjugate cyclostationary ,since E{ for M-PSK(M≠2) or QAM modulation types, given that is centered and i.i.d . hence,.

It is easily seen that is periodic in t with a period equal to Ts ,hence the OFDM signal exhibits non conjugate cyclostationary with a cycle frequency ,k=0,1, and cyclic autocorrelation function can be calculated as:

with assumption Fourier Transform of ,CAF can be expressed as :

taking Fourier Transform of the CAF leads to the SCD function: (33)

**C. Cyclostationary Characteristic of a GMSK signal:**

Gaussian minimum shift keying (GMSK) modulation, employed in GSM can be interpreted as a 2-level FSK modulation index h=0.5 . the complex envelope of a GMSK signal is :

with symbol sequence , symbol rate fs=1/Ts  and frequency impulse g(t) given as :

is a Gaussian impulse with the time bandwidth product BTs. For the GSM system ,the factor BTs=0.3 was chosen. In practical, the Gaussian impulse is cut to a length LTs .A GMSK signal with L=4 can be represented as the superposition of a linear and non-linear component the linear part slin(t)can be used to approximated the GMSK signal: s(t)slin(t)=

with modulating symbol sequence:

zn=exp[j π h]=jdnzn-1

and:

using this approximation, the conjugate time variant autocorrelation function of signal can be calculated as:

Rss\*(t,τ)≅E{slin(t-𝜀)slin(t-𝜀+τ)}=

with the unknown symbol timing 𝜀 and constant ∈{-1,1}.Obviously , Rss\*(t,τ) is periodic with period equal 2Ts. Leading to a conjugate cyclostationary with cycle frequencies αk=k/2Ts for integer k. Expressing

c0(t) in terms of its Fourier Transform C0(θ) ,and rearrange the term ,we can write:

(36) 

and:

(37)

It can be shown that GMSK signal also exhibits

non conjugate cyclostationary with the

fundamental cycle frequency αf=1/Ts .The non conjugate CAF and SCD functions for this case can be calculated

C0(f) in GSM is relatively narrowband function.

1)the spectral overlapping term C0(θ)C0( in (36),(37) are almost zero except for k= ,leading to an almost complete suppression of Rss\*(τ),Sss\*(f) for higher harmonics of the fundamental frequency αf= .

2)the spectral overlapping term C0(θ)C0\*(k/Ts-θ) in (38) ,(39) is so small leading to an almost total suppression of the non conjugate CAF and SCD functions for any integer k≠0. The extraction of the CAI requires the detection of the presence of the cyclic statistics of the GMSK based LS signal under interference from the OFDM based RS signal. Since, the OFDM signal does not exhibit conjugate cyclostationary and the GMSK signal exhibits a strong conjugate cyclostationary but a faint non-conjugate cyclostationary ,exploiting conjugate cyclic statistics as a feature for detection is the logical choice for given task.

**D. Detection Statistic:**

The presence detection of the LS signal under interference from RS reduces itself into the detection of the presence of conjugate cyclostationary in the receive composite signal x(t)=s(t)+i(t) with cycle frequencies αfs/2 at each GSM sub band, where s(t) and i(t) the contributions from the LS and RS, respectively, and fs is a symbol rate of the GSM system. For the presence detection of the LS signal in one sub band ,we can formulate the following binary hypothesis testing problem. Let H1 represented the case where both the LS and RS are present in the channel and H0 represent the case that only the RS signal is present in channel ,then: [6]   
(40)

Where fs' is product fs and Tst(sampling time receive signal).

**8. Combined spectrum pooling and adaptive bit loading for cognitive radio OFDM based system:**

In this section ,we want to present the combination of adaptive bit loading and spectrum pooling to be applied in a cognitive radio OFDM based system.

At first , we want to describe adaptive bit loading and spectrum pooling idea and finally we show combination of them.

**A. Adaptive Bit Loading:**

Based on the channel fading information from the channel estimation process in OFDM ,constellation size of each subcarrier is determined .There are some algorithms for implementing of it and each of them has its own optimization criterion. In following , we describe some of them:

**Chow algorithm:**

This algorithm tries to maximize the available amount of noise while it can achieve the target bit error rate and has this equation :

where is the number of allocated bits in subcarrier n.

**Fischer Huber algorithm:**

The purpose of this algorithm is to be minimize BER per OFDM symbol. The bits are allocated according to the equation defined (42).

**Simple Block wise Loading Algorithm:**

Grouping of the subcarriers into several sub bands is intended .The modulation mode of each group is selected based on the location of the average SNR of the group.

**Sub band Bit Loading based on Fischer- Huber Algorithm :**

Equation (42) can be modified in order to have

bit allocation per sub band:

And with assumption using a window (such as raised cosine, rectangular ,Bartlett, better than raised cosine) for reducing interference with LS spectrum of the transmitted OFDM signal has the form as given (44):

Where X(f) is OFDM spectrum ,Sn is the modulated signal on carrier n, g(t) is a window function and fn is the frequency of carrier n.

This equation shows that the OFDM power density spectrum is determined by the constellation size of the modulated data ,α, and the window form. The larger constellation size of the carrier the higher possibility of occurring high power spectral density ,which means that the interference to the system adjacent to the RS OFDM system becomes higher. With evaluation of simulation results ,we conclude combination of Fischer adaptive bit loading with the long better than raised cosine window is a promising method in cognitive radio system

[7]**.**

**9**.**CONCLUSION:**

In this work, we introduced a new strategy called spectrum pooling enabling public access to the new spectral ranges without sacrificing the transmission quality of the actual license owner or requiring any new hardware in the original licensed system .In this letter ,we reviewed different aspect of OFDM based Spectrum Pooling. At first, we demonstrated Spectrum Pooling scenario, then , said energy detection as a method detection and mutual interference and false alarm , detection probabilities in this method. We presented a strategy for the extraction of the CAI in the Spectrum Pooling ,which is based on exploiting the disparate cyclostationary characteristics of the LS and

RS signal. Finally, we defined adaptive bit loading combined spectrum pooling following kinds of different windows.

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