IEEE 1900.7 White Space Radio TVWS Access with Polarization Adaption

Date: **2013-3-13**

Authors:

Name	Company	Address	Phone	Email
Dongming Li	BUPT	No.10 Xitucheng Road,Haidian, Beijing China	+86-010-62283238	lidongming1986@gmail.com
Caili Guo				guocaili@gmail.com
Zhimin Zeng				zengzm@bupt.edu.cn
Xiaoming Li				lixiaoming_andy@163.com
Yuting Guo				gyt265@bupt.edu.cn
Yao Liu				liuyao@bupt.edu.cn

Abstract

- Based on the call for contributions 1900.7-11/00 63r0, we present TVWS access based on Polarization Adaption (PA) in this document.
- The principle and realization block of PA is presented.
- ACLR Performance for PA is investigated.
- Further application of PA into LTE is studied as a case.

Background (1/3)

- P1900.7 general requirement (1900.7-12-0021-r1) identifies that:
  - "The P1900.7 shall provide means to protect primary systems according to the national and international radio regulations."
  - "The P1900.7 shall support multi free bands for secondary users access."
- This means that P1900.7 shall be able to operate with a minimal interference to potential adjacent primary user.
- P1900.7 has selected TV band as target frequency band. Therefore TVWS parameters will be used for quantitative evaluation and comparison without any loss of generality.
- Polarization transmission has been worldwide supported by national terrestrial TV regulators, such as ATSC, DVB-T, ISDB-T for digital TV broadcasting [1-7].

Background (2/3)

Major Terrestrial Digital TV Broadcasting Standards

Nation/Region	Regulator	Polarization Pattern
USA	ATSC	Vertical, Horizontal, Elliptical (for MMB)
Europe	DVB-T	Vertical, Horizontal, Elliptical (for MMB)
Japan	ISDB-T	Vertical, Horizontal
PRC	DMB-TH (GB20600-2006)	Horizontal

MMB: Mobile Multimedia Broadcasting

Background (3/3)

- Polarization discrimination between DTV specifically polarized antenna and that of WSD (White Space Devices) can be exploited to achieve performance requirements set by regulators.
- Polarization Adaption — WSD could adjust the polarization state by changing the amplitude ratio and phase difference between two orthogonal components of its transmitted signal electromagnetic wave to achieve polarization mismatch with the specific polarization pattern of the incumbents, by which interference is avoided.

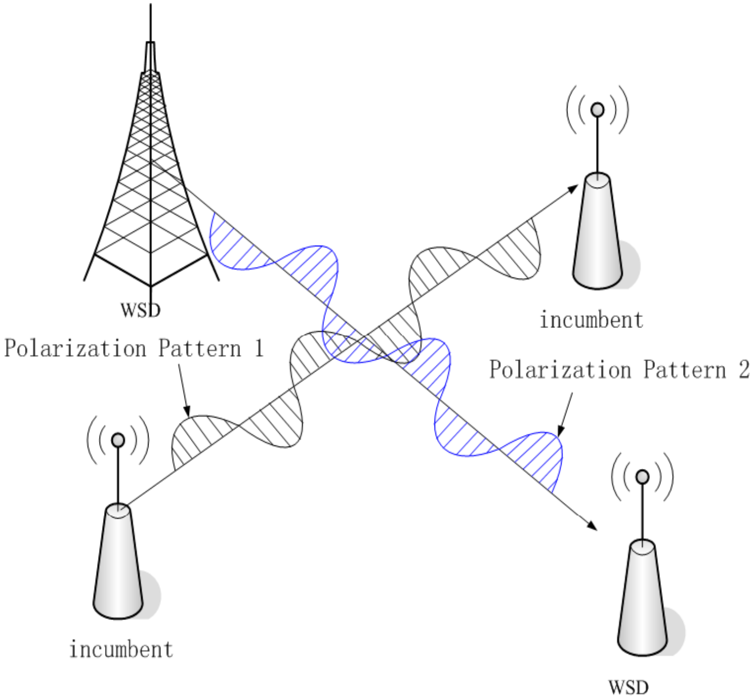
[1] KATHREIN. ”50 Years of Kathrein FM & TV Broadcasting Antennas & Antenna Systems (1955-2055)”. Antennen·Electronic.
[2] Jay Adrick. “ATSC Mobile DTV Implementation Overview”. HARRIS. October 2011
[3] Kenichi MURAYAMA, Makoto TAGUCHI, Takuya SHITOMI, Hiroyuki HAMAZUMI, Kazuhiko SHIBUYA. “Transmission Technologies for Next-generation Digital Terrestrial Broadcasting—Increasing Transmission Capacity toward Super Hi-Vision”. ATSC 2010 Symposium on Next Generation Broadcast Technology. October 2010
[4] Toru Kuroda. “Preparations for the Full Digitalization of Broadcasting”. Broadcast Technology. No 41. Summer 2010
[5] “DVB-T in der Praxis (Ein Leitfaden für den Fachhandel)”. DVB-T: DasüberallFernsehen.
[6] Jay Adrick. “ATSC M/H Station Implementation”. HARRIS.
[7] “Mobile/Handheld DTV Antenna Systems, Broadband Solutions”. MCI. September 2010

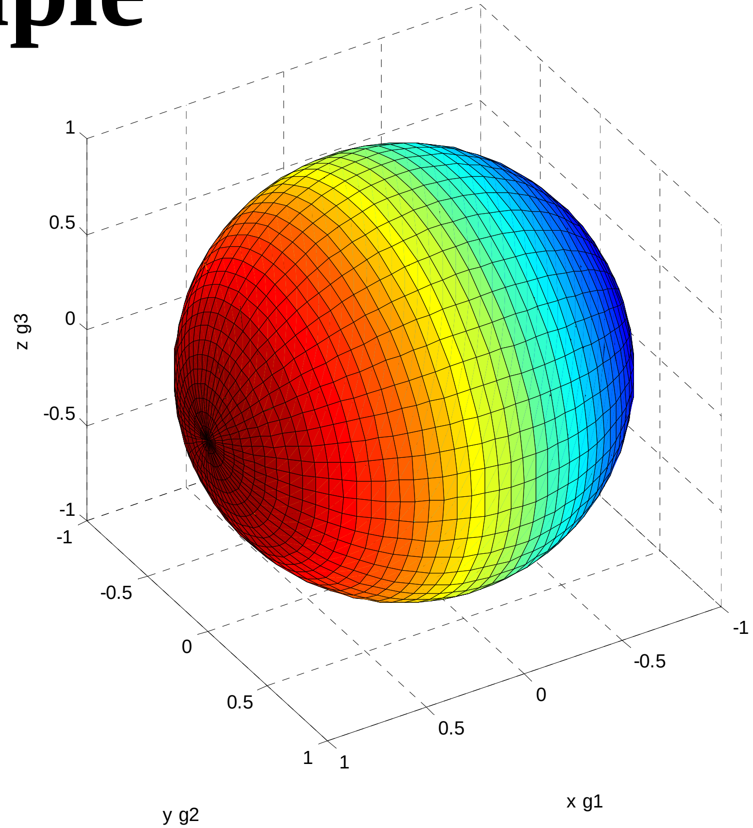
Proposed solution ~principle

- The similarity of two Polarization States (PSs) generally represents the difference between them [8], and the value of polarization similarity varies from 1 to 0, as the relationship of two PSs varies from identical to orthogonal.
- The greater the value of polarization similarity between incoming electromagnetic wave and the receiving antenna, the more power of the incoming electromagnetic wave will be received, and vice versa.
- When polarization similarity value between PSs of incoming electromagnetic wave and the receiving antenna is 1, the power of electromagnetic wave is totally received, while the value is 0, no power will be received.

[8] Z. W. Zhuang, Y. Z. Li, ``Statistical characteristics and Processing of Instantaneous Polarization,'' \emph{National Defence Industry Press}, 2005.

Proposed solution ~principle





- The power is totally received (red) when polarization states matched and little is received (blue) when mismatched.

Proposed solution ~to ACLR problem

- 3GPP TS25.101 (section 6.6.2.2) sets requirements on ACLR measurement for mobile phones, Adjacent Channel Leakage power Ratio (ACLR) is “the ratio of the transmitted power to the power measured after a receiver filter in the adjacent channel(s)”.
- The power of OFDM signal from WS transmitter will decrease after passing through channel, and the power measured at incumbent after a receiver filter in the adjacent channel(s) is smaller than originally transmitted power.
- The decrement of power in adjacent channel(s) originates from transmission loss and reception loss.
- The aforementioned polarization mismatch contributes to the reception loss.

Proposed solution

- Thus, in addition to techniques adopted at transmitter, two more factors should be taken into account for the problem of applying OFDM into TVWS.
- 1. With geo-location database available, the pathloss of propagation environment between incumbent receiver and WS transmitter should be taken into account.
- 2.The polarization mismatch at incumbent receiving antenna will also degrade the received interference power.

LTE extension to TVWS – a case study ~ Feasibility Consideration

- According to 3GPP TR 36.814, up to 8 transmitting antennas are supported for E-UTRA, co-polarized or cross-polarized (ODPA):

  | | | | or X X X X

  ODPA could transmit and receive any polarization state. Thus, the antenna configuration provide LTE nodes opportunities to suppress ACLR on incumbent receivers.

- Deployment of polarization adaption on LTE transceivers has another congenital advantage:

  As LTE adopts OFDM, polarization state for LTE is adapted on subcarriers (typically15kHz), for such range of spectrum band, transmission will not be deteriorated by depolarization effect such as Polarization Mode Dispersion (PMD).

PA to change polarization similarity

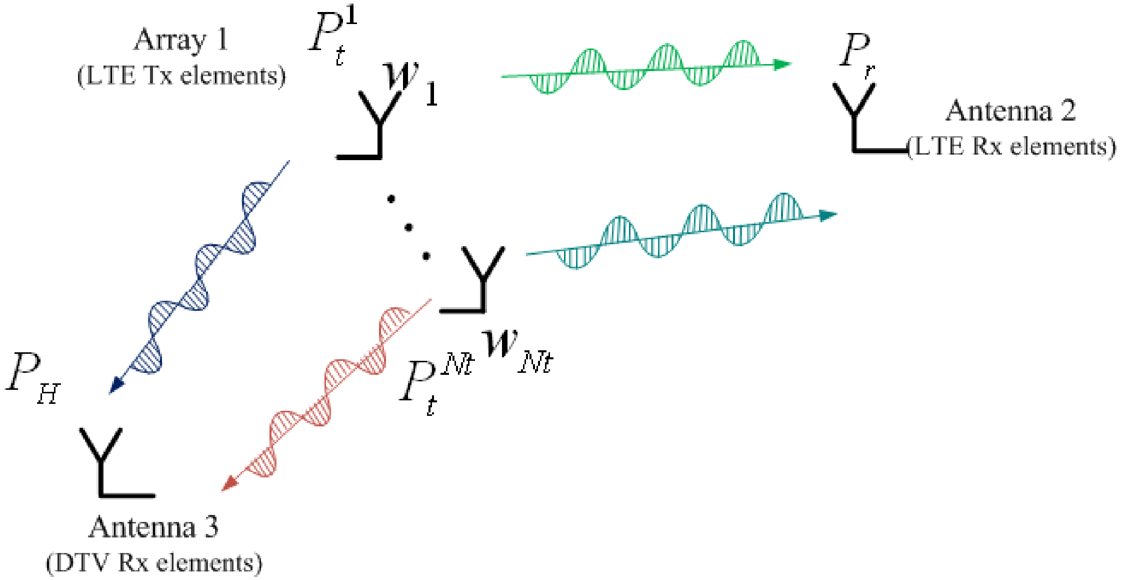
- The reception loss in PSs should be represented by polarization similarity between PS of incoming electromagnetic wave (H P_t) and PS of incumbent antenna P_r , polarization similarity is

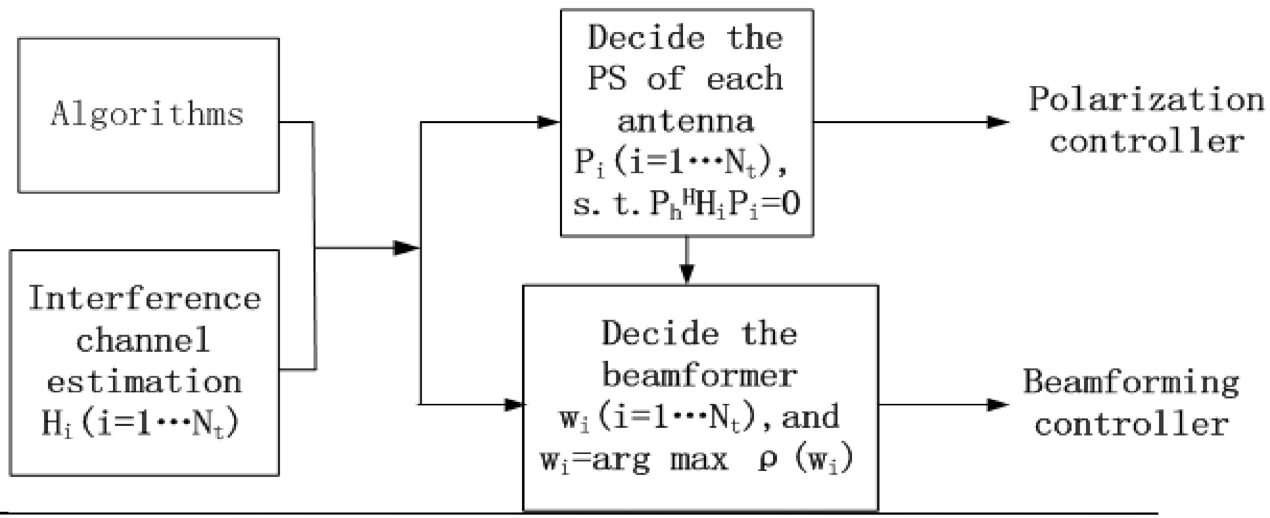
$$\rho = \left| (\sum_{i=1}^{N} w_i h_i^s H_i^p P_t^i)^H \cdot P_H \right|$$

- P_H is the reception PS (vertical or horizontal) of incumbents, P_t^i is the transmitting PS of the *i*th LTE transmitting antenna. h_i^s and H_i^p respectively characterize the spatial and polarized fading nature of the environment. Beamformer w_i adopted by LTE effects on the transmitting PS P_t^i and eventually changes ρ.
- Thus, ω_i can be adapted to control the power ultimately received by incumbent antenna, and ACLR required by FCC and OFCOM can be fulfilled.

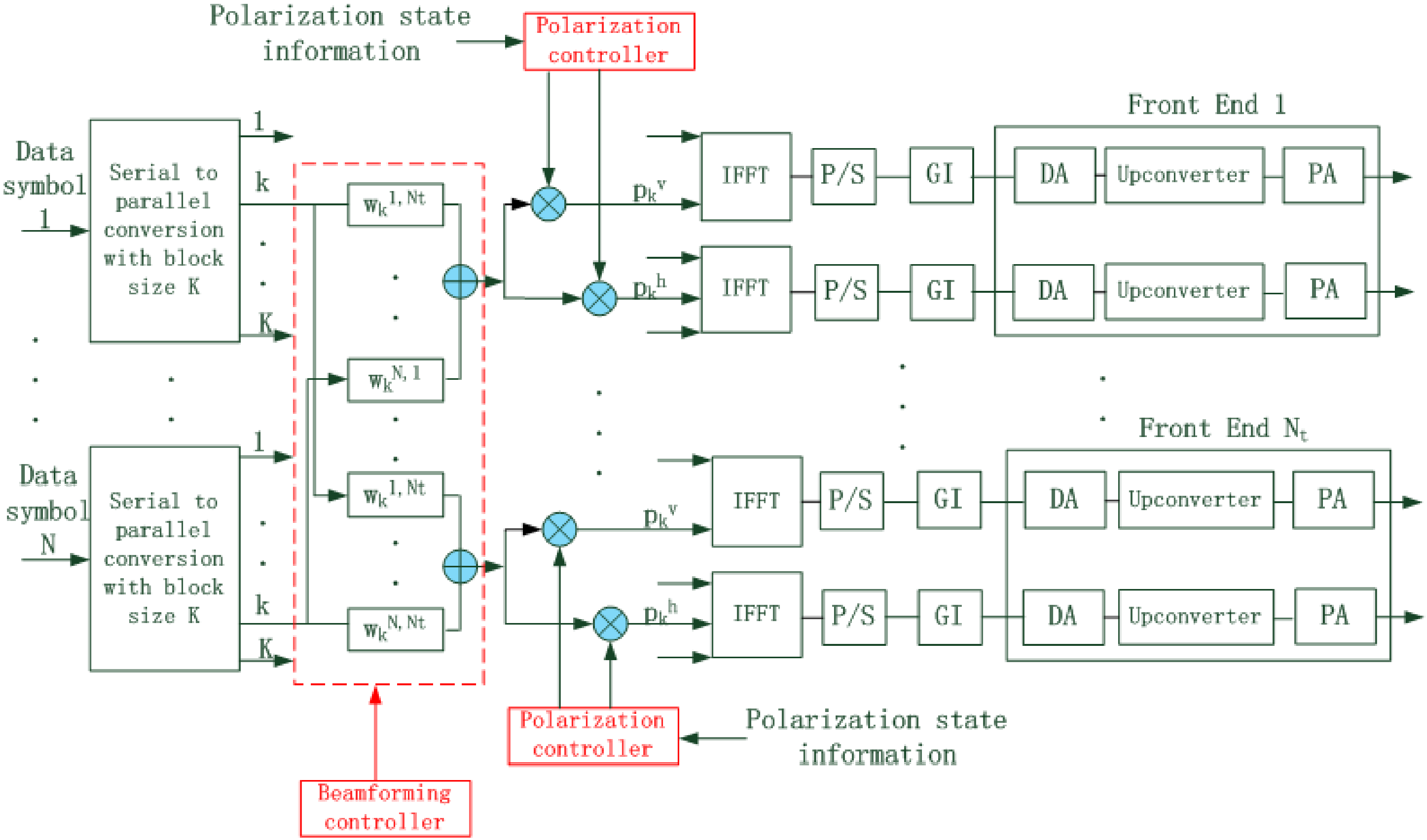
What does it take to perform PA?

Polarization adaption of LTE transmitter should be constrained to get the desired polarization mismatch to reduce OOB level first, then the concrete polarization state is designed to optimize the LTE link performance based on the constraint.

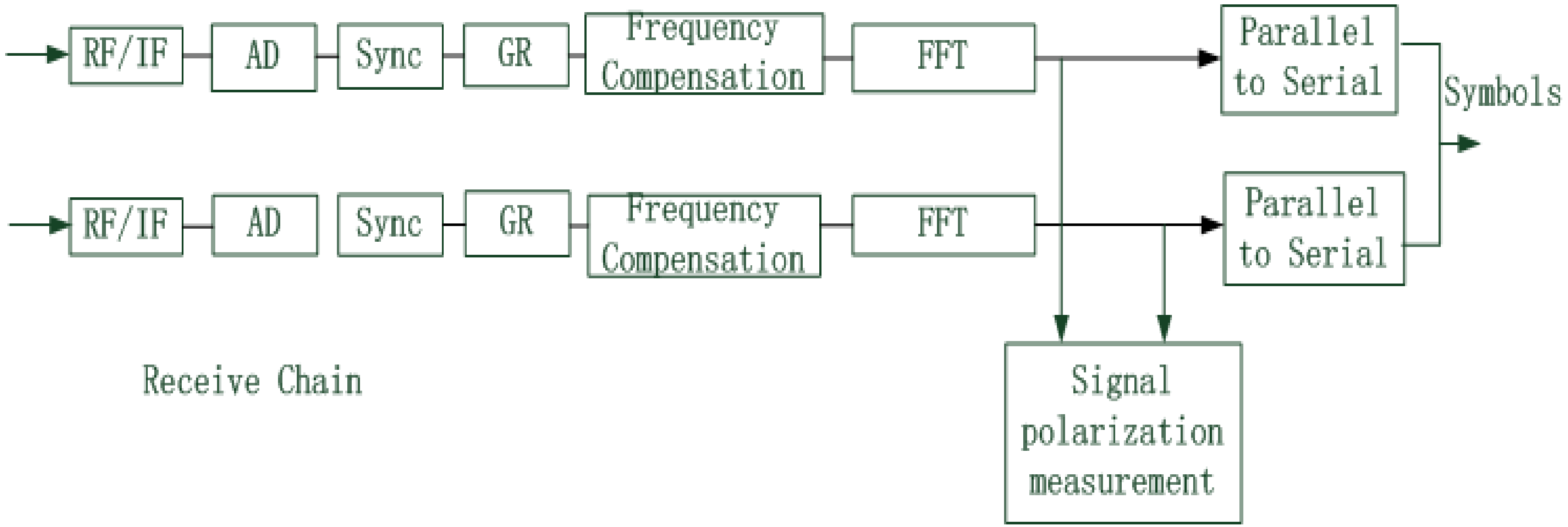




Transmitter



Receiver


RF/IF
AD
Sync
GR
Frequency Compensation
FFT
Parallel to Serial
RF/IF
AD
Sync
GR
Frequency Compensation
FFT
Parallel to Serial
Symbols
Receive Chain
Signal polarization measurement

Performance Evolution

- Under the same LTE transmitting power P_0, according to FCC, the leakage power on adjacent channel(s) to achieve 55dB and 45 dB are P_{55} and P_{45}, and

$$10\log_{10}\frac{P_0}{P_{55}} = 55, \quad 10\log_{10}\frac{P_0}{P_{45}} = 45$$

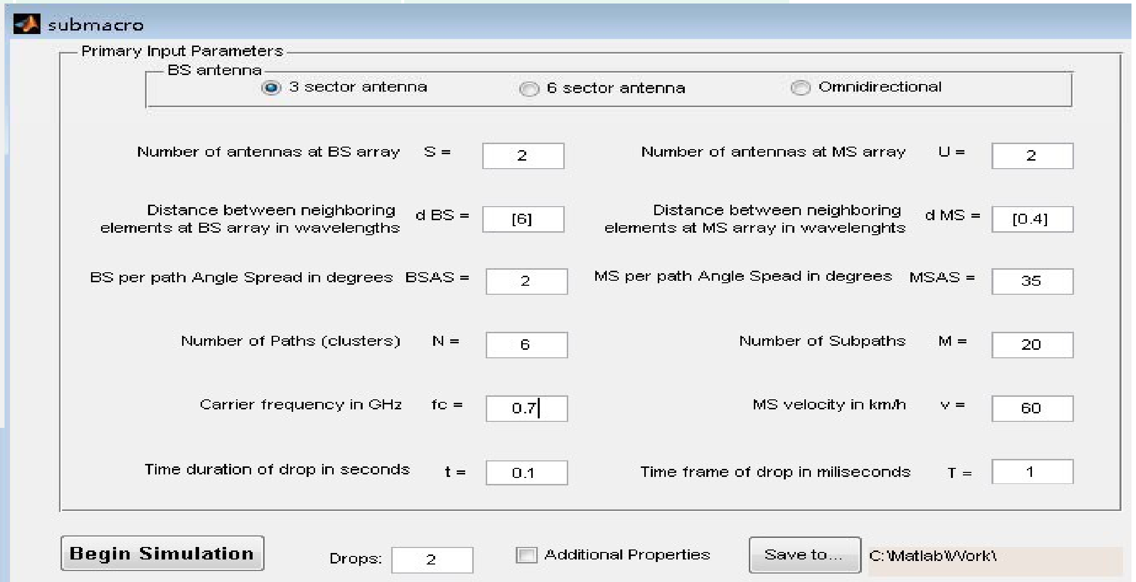
then

$$\frac{P_{55}}{P_{45}} = \frac{P_0/10^{5.5}}{P_0/10^{4.5}} = 0.1$$

thus, the leakage power on adjacent channel(s) at the incumbent receiver should be 0.1 times of original leakage power in order to fulfill the TVWS ACLR requirement.

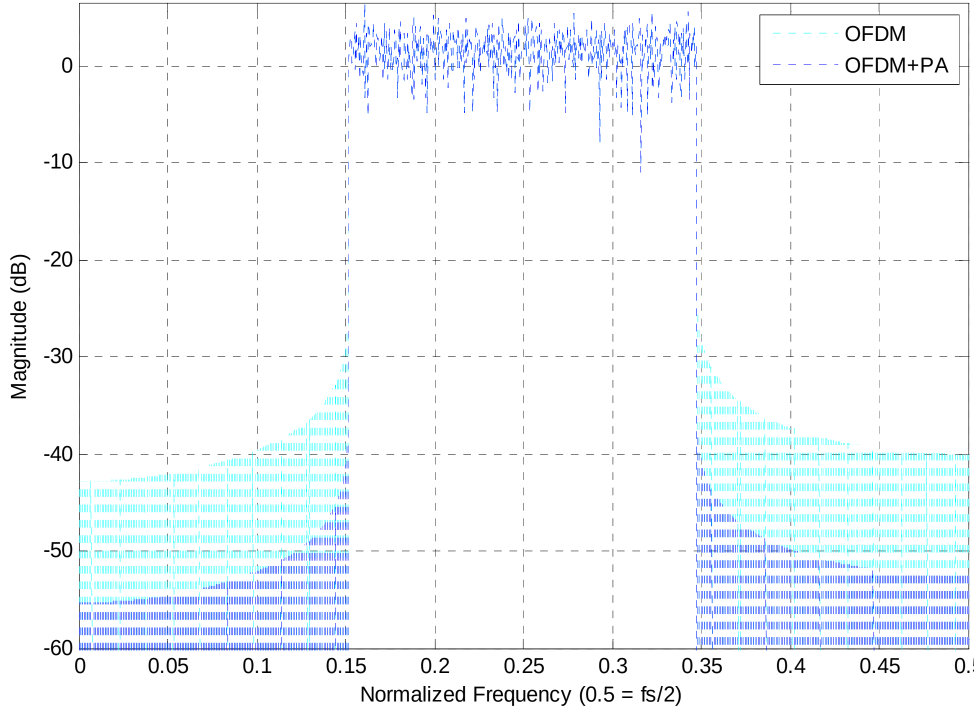
Performance Evolution

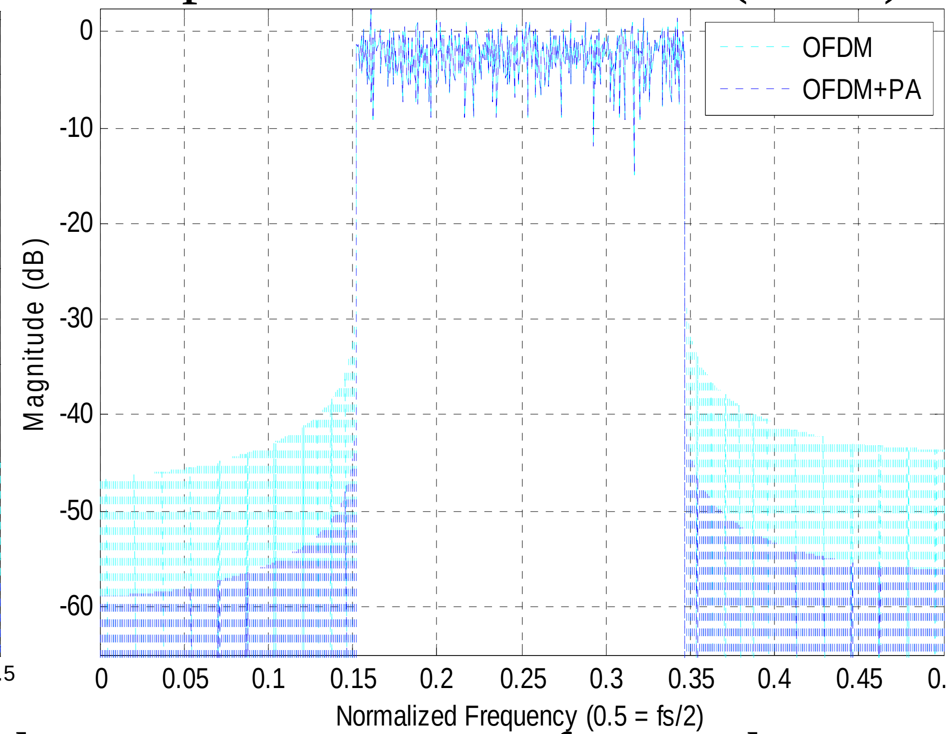
Parameters	Suburban macro	Urban macro
Distance	1000m	
Antennas	2x2	
MS velocity	60km/h	
Carrier frequency	700MHz	
Pathloss	137.35	140.35
XPD	15dB	20dB



Performance Evolution

- LTE receive spectrum is evaluated with Space Channel Model (SCM).

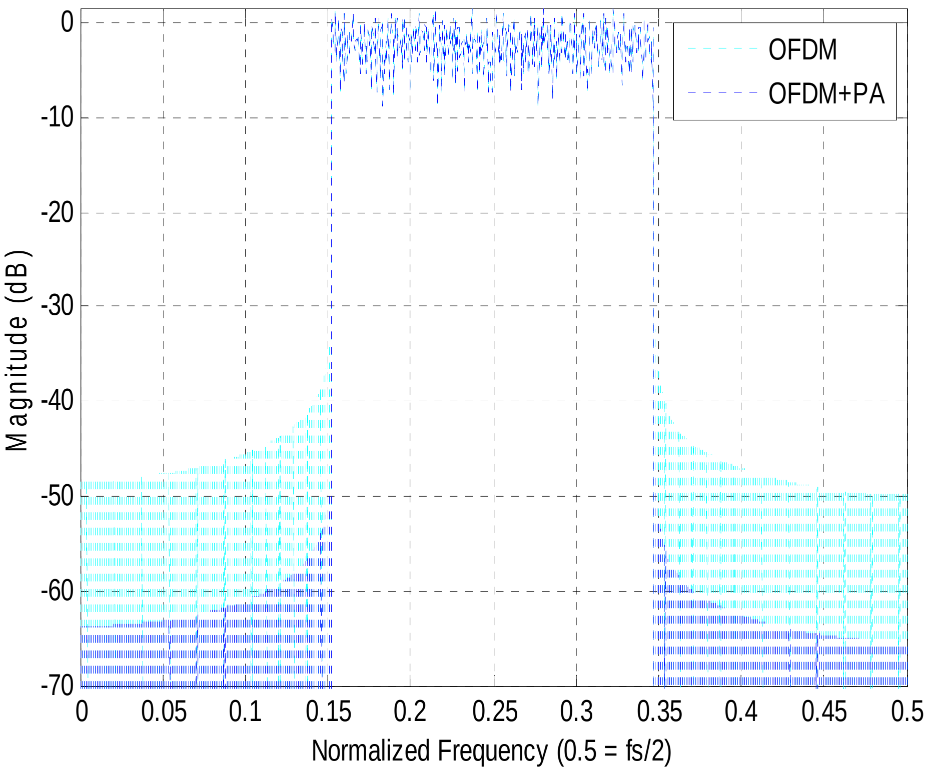


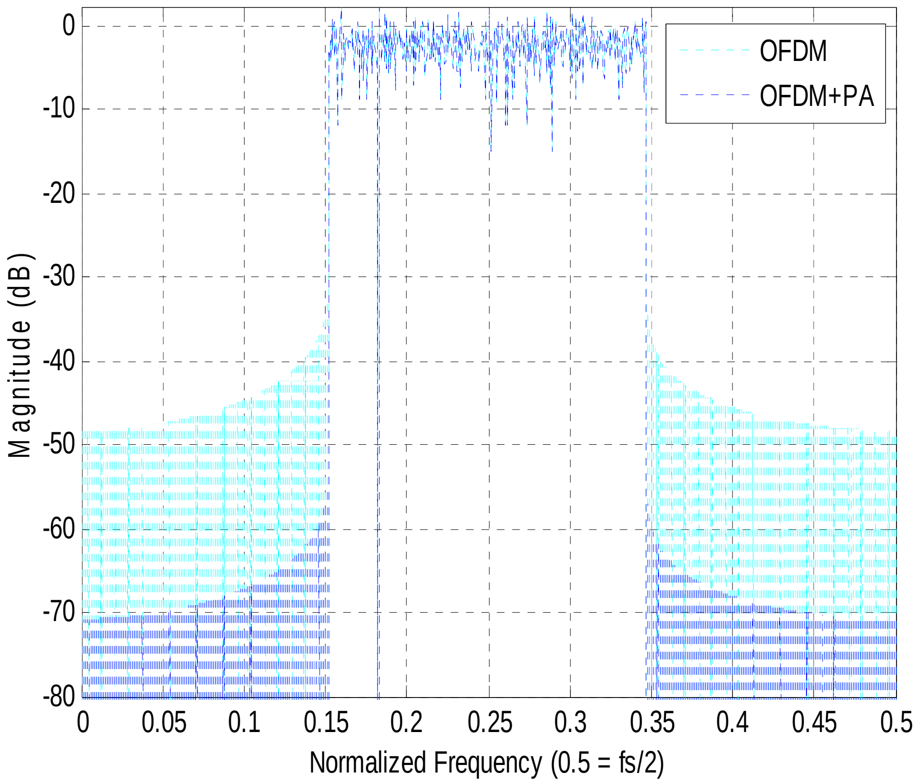


- For both urban and suburban area, the power spectrum of incumbent receiver in adjacent channels are degraded with PA technique.
- The ACLR for the two scenarios can be both improved to 55dB with $\rho \leq 0.1$

Performance Evolution

Spectrum with consideration of polarization mismatch and pathloss.





- For both urban and suburban area, the power spectrum of incumbent receiver in adjacent channels are further degraded with pathloss considered.

Conclusion

- Polarization Adaption technique is well-suited for white-space radio, the WSD should adapt its transmit parameters (polarization state etc) for suppressing interference to incumbents and enhancing the wanted signals.
- PA is especially promising in LTE for ODPA and OFDM are supported.