Simultaneous Transmit and Receive (STR) Relaying

Document Number: **S802.16m-10/0202**
Date Submitted: **2010-03-07**

Source:
Chanho Min, Heewon Kang, Youngbin Chang
Seunghee Han, Youngsoo Kim Email: chanho.min@gmail.com , hkang@samsung.com, yb.chang@samsung.com

Samsung Electronics

Venue: **IEEE Session #66**

Re: **IEEE 802.16-10/0011, IEEE 802.16 Working Group Letter Ballot Recirc #31 / Topic: Relay Format (Section 16.6.1)**

Purpose: **To be discussed and adopted by TGm for P802.16m/D5**

Notice:

This document does not represent the agreed views of the IEEE 802.16 Working Group or any of its subgroups. It represents only the views of the participants listed in the "Source(s)" field above. It is offered as a basis for discussion. It is not binding on the contributor(s), who reserve(s) the right to add, amend or withdraw material contained herein.

Release:

The contributor grants a free, irrevocable license to the IEEE to incorporate material contained in this contribution, and any modifications thereof, in the creation of an IEEE Standards publication; to copyright in the IEEE's name any IEEE Standards publication even though it may include portions of this contribution; and at the IEEE's sole discretion to permit others to reproduce in whole or in part the resulting IEEE Standards publication. The contributor also acknowledges and accepts that this contribution may be made public by IEEE 802.16.

Patent Policy:

The contributor is familiar with the IEEE-SA Patent Policy and Procedures:
<http://standards.ieee.org/guides/bylaws/sect6-7.html#6> and <http://standards.ieee.org/guides/opman/sect6.html#6.3>.
Further information is located at <http://standards.ieee.org/board/pat/pat-material.html> and <http://standards.ieee.org/board/pat >.

Motivation

- The STR relaying has been adopted as one of the relaying options in the 802.16j standard.
  - Simultaneous communication with subordinate station(s) and the superordinate station is performed on the same carrier frequency or different carrier frequencies.

- Allowing STR relaying is not accompanied by significant changes in the current standard draft.
  - Does not require any new management message, new field in existing messages and so on.

STR Relaying

- Two kinds of STR relaying are possible :
  - STR relaying on different carrier frequencies
    - In general, the term “outband relaying” is used for this case.
  - STR relaying on the same carrier frequency
    - It differs from repeater in that ARS decodes the received data and is able to reschedule it.
    - Also, it can use different MCS levels which is appropriate for channel condition.

STR Relaying on the Same Carrier

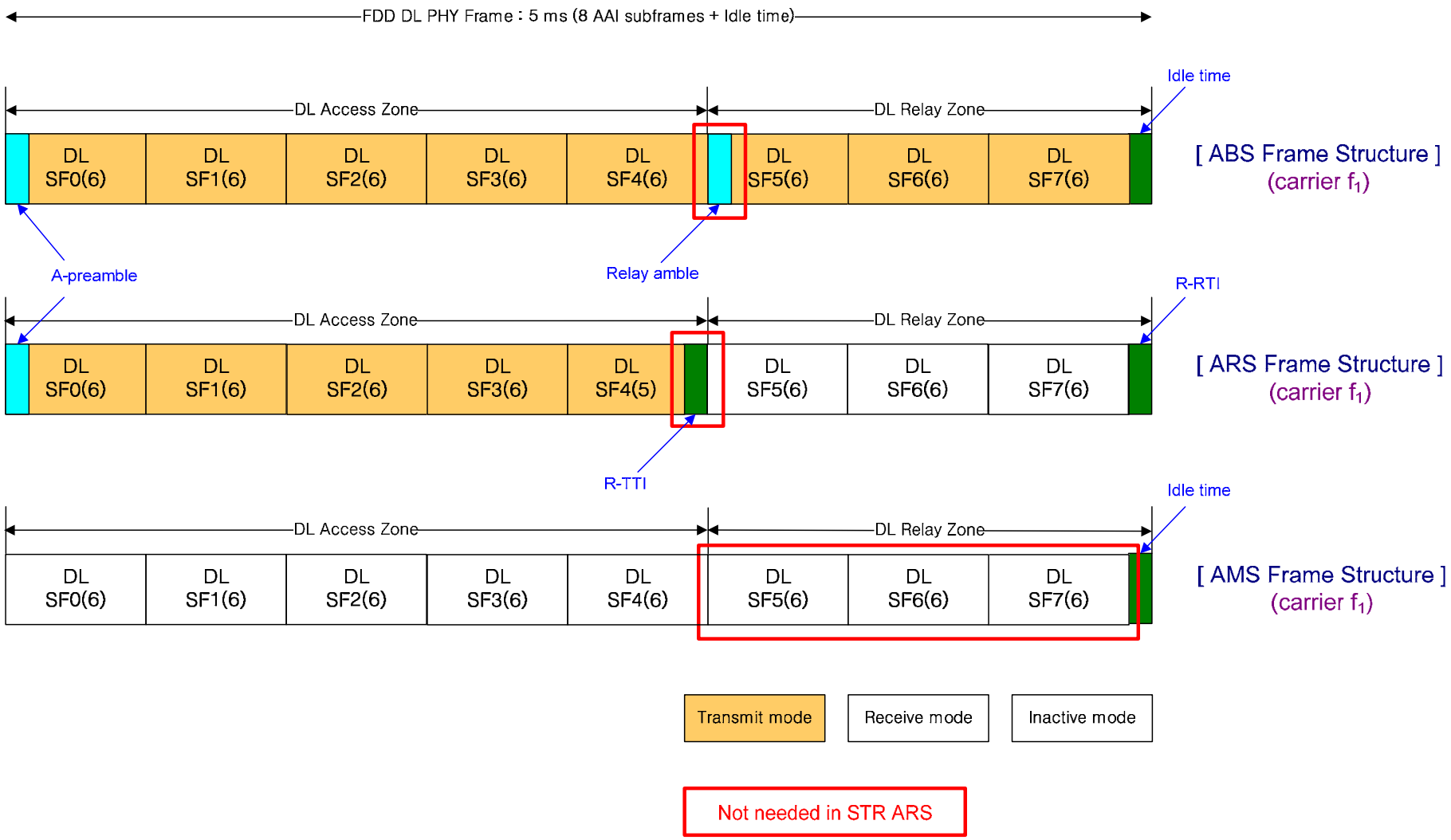
- Expected benefits
  - Potential increase in spectral efficiency
    - Re-utilizes ABS-ARS link resources as ARS-AMS link resources
  - Reduced overhead
    - No need for switching gap (R-TTI and R-RTI), relay amble, and broadcasting information for frame configuration
  - Lager uplink coverage
    - Long TTI can be applied to the whole UL frame which is not divided by Relay zone and Access zone.

- Potential impact, but solvable (Refer to Appendix A, B)
  - Needs to reduce interference from relay TX to relay RX

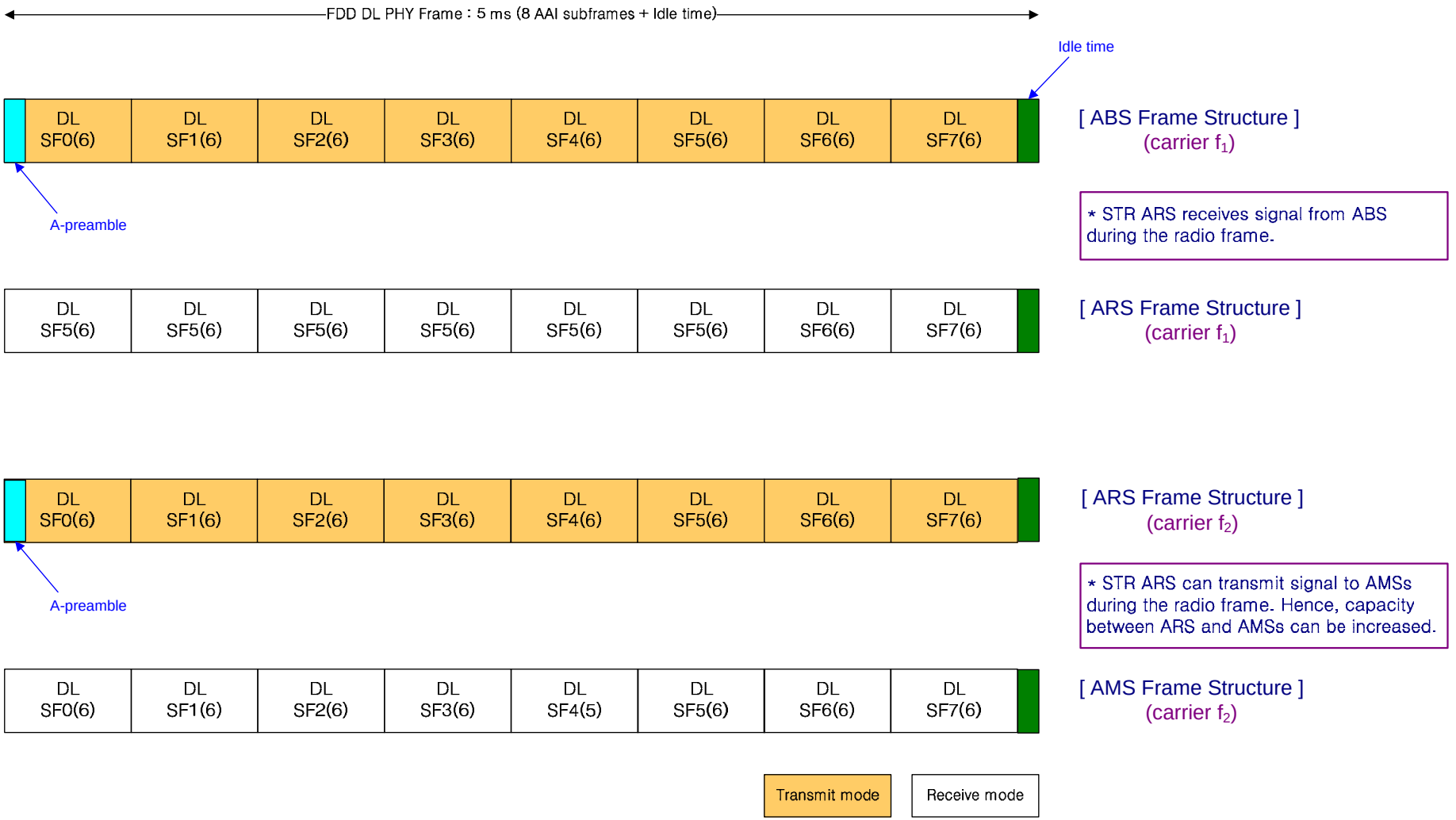
Comparison of Three Relaying Options

Aspects to be clarified	**TTR relaying**	**STR relaying on different carriers**	**STR relaying on the same carrier**
# of antennas sets needed	(+) One antenna set	(-) Two antenna sets	(-) Two antennas sets
Additional carrier frequency	(+) Not required	(-) Required	(+) Not required
Zone configuration	(-) Required (Access zone & Relay zone)	(+) Not required	(+) Not required
R-TTI & R-RTI	(-) Required	(+) Not required	(+) Not required
Relay amble	(-) Required	(+) Not required	(+) Not required
Spectral efficiency	(-) Low	(-) Very low	(+) High
Loss in uplink coverage	(-) Yes	(+) No loss	(+) No loss
Self-interference at Relay	(+) No	(+) No	(-) Yes

FDD DL PHY Frame Structure (when TTR ARSs are supported)

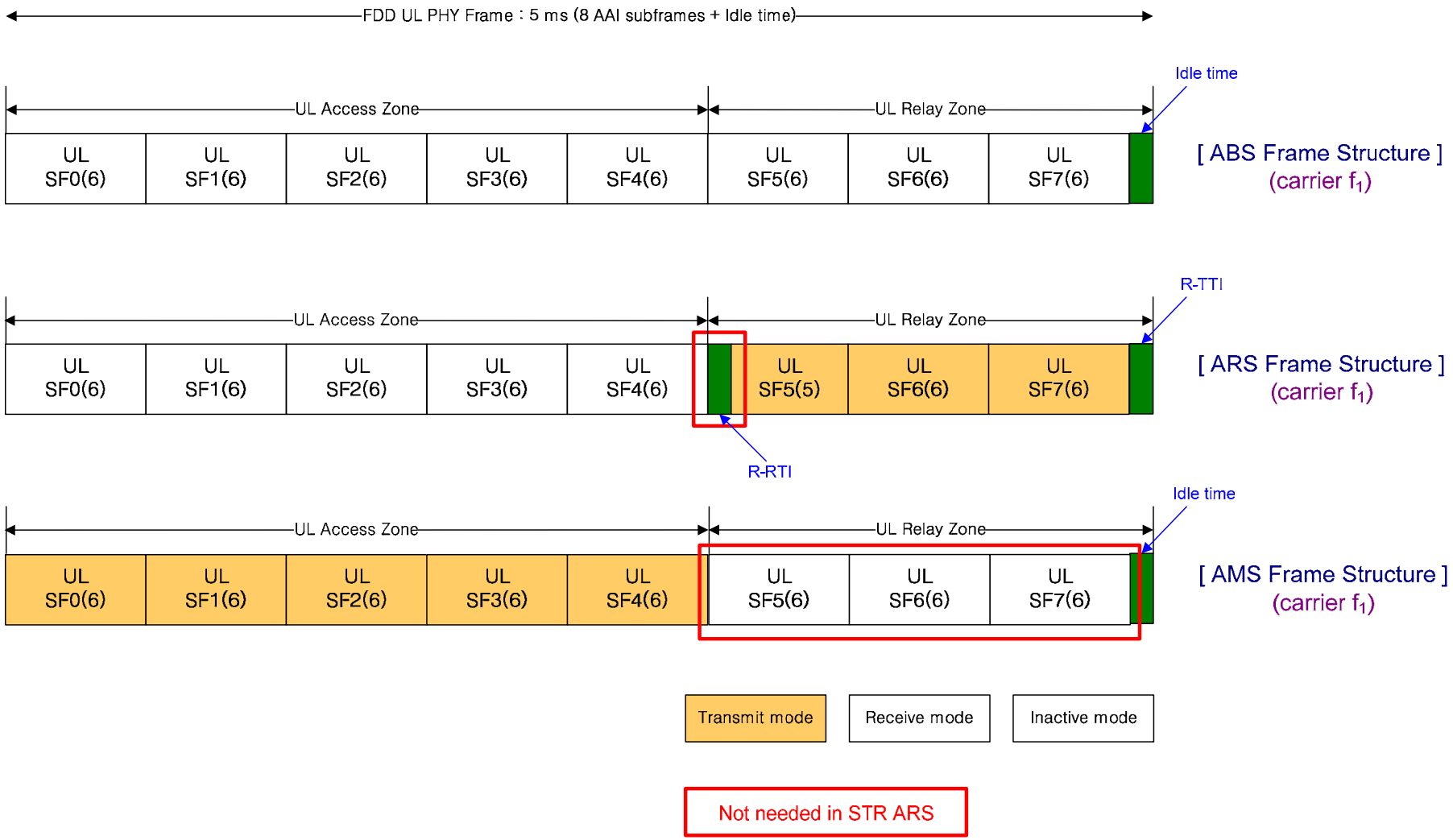


FDD DL PHY Frame Structure (when STR ARSs are supported)

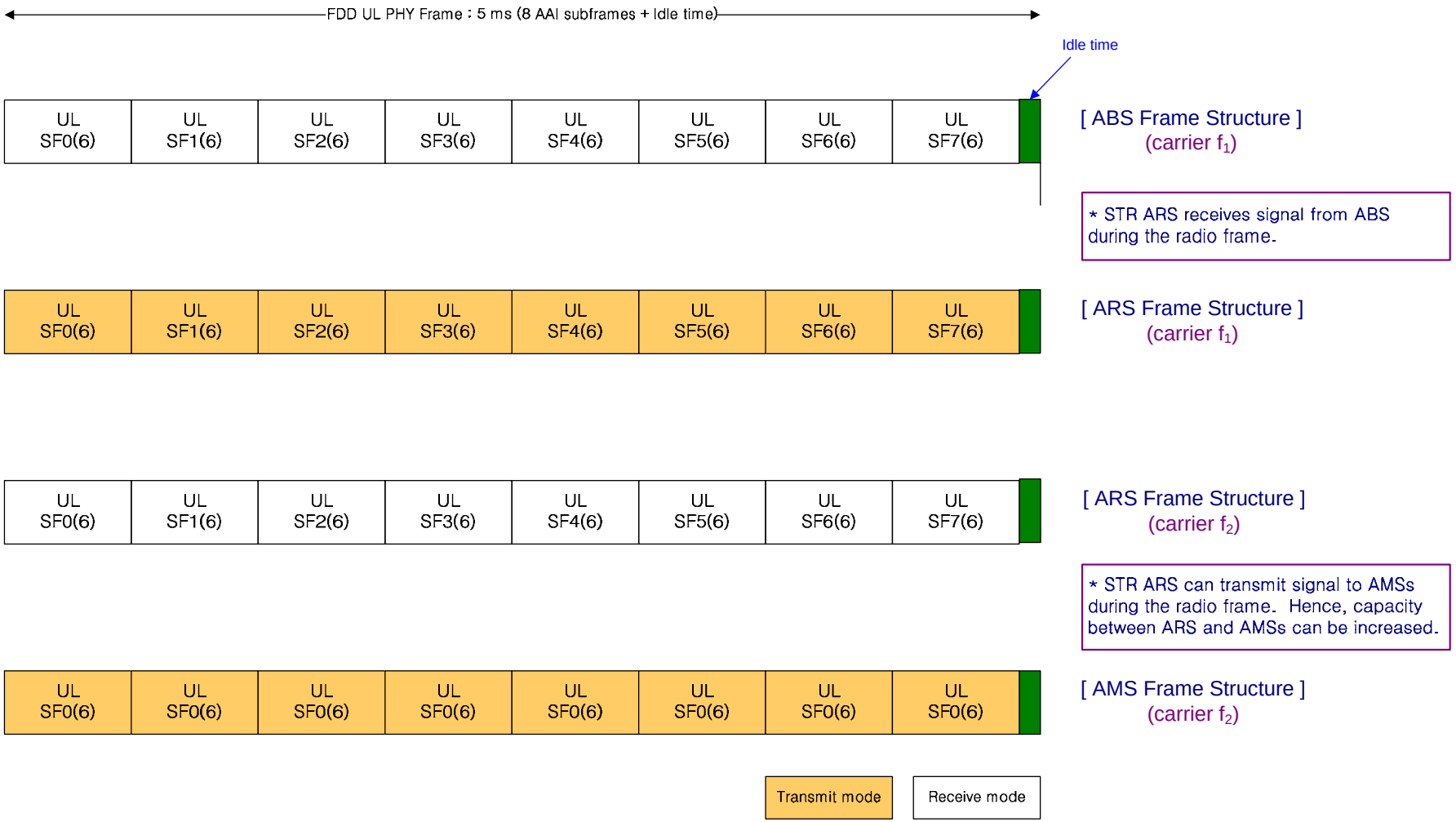


✓ **Carriers f_1 and f_2 can be the same or different.**

FDD UL PHY Frame Structure (when TTR ARSs are supported)

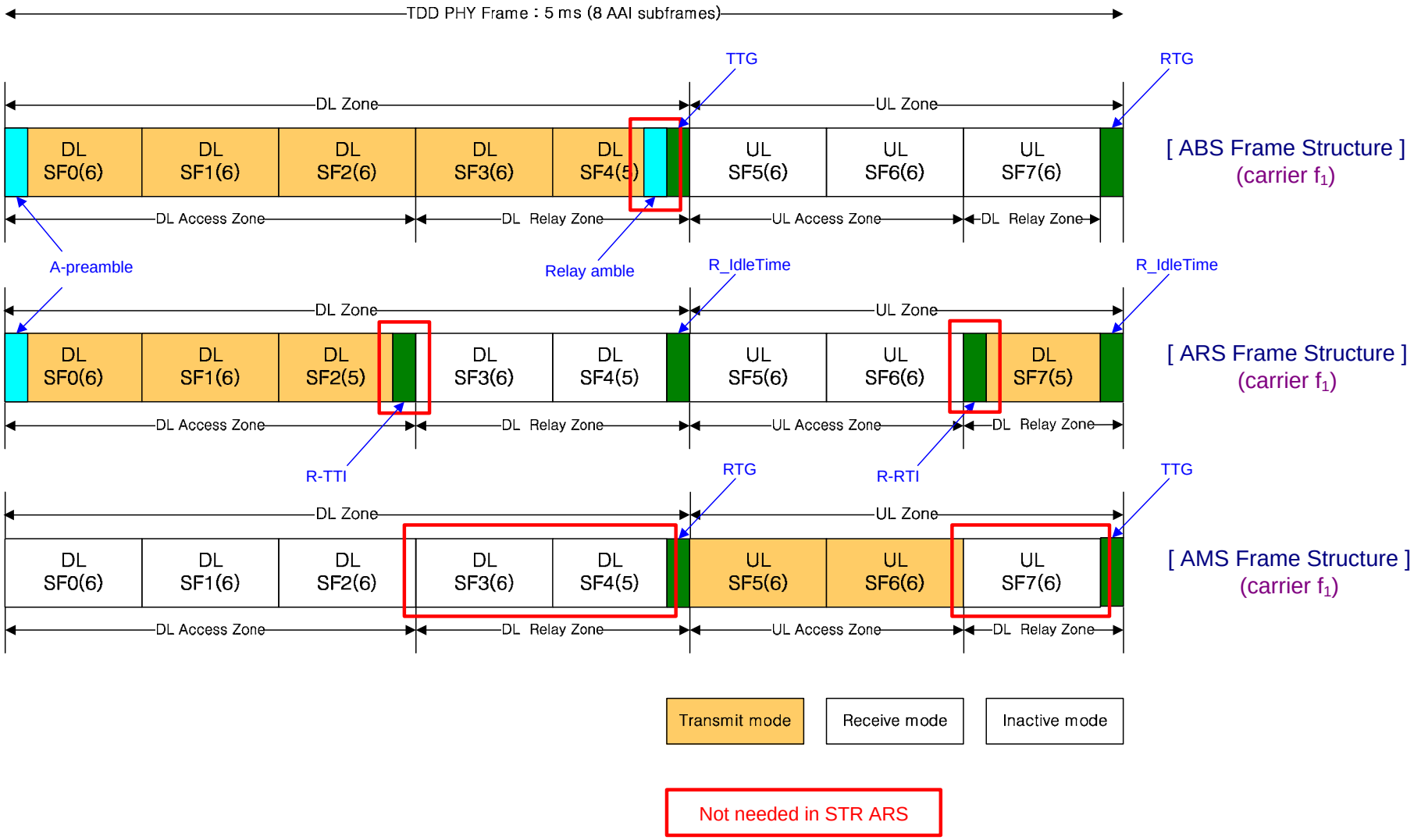


FDD UL PHY Frame Structure (when STR ARSs are supported)



✓ **Carriers f_1 and f_2 can be the same or different.**

TDD PHY Frame Structure
(when TTR ARSs are supported)



TDD PHY Frame Structure (when STR ARSs are supported)

[ABS Frame Structure]
(carrier f_1)

* STR ARS transmits/receives signal to/from ABS in DL/UL zone.

[ARS Frame Structure]
(carrier f_1)

[ARS Frame Structure]
(carrier f_2)

* STR ARS can transmit/receive signal to AMSs in DL/UL zone. Hence, capacity between ARS and AMSs can be increased.

[AMS Frame Structure]
(carrier f_2)

Transmit mode | Receive mode

✓ **Carriers f_1 and f_2 can be the same or different.**

Proposed AWD Text Modification

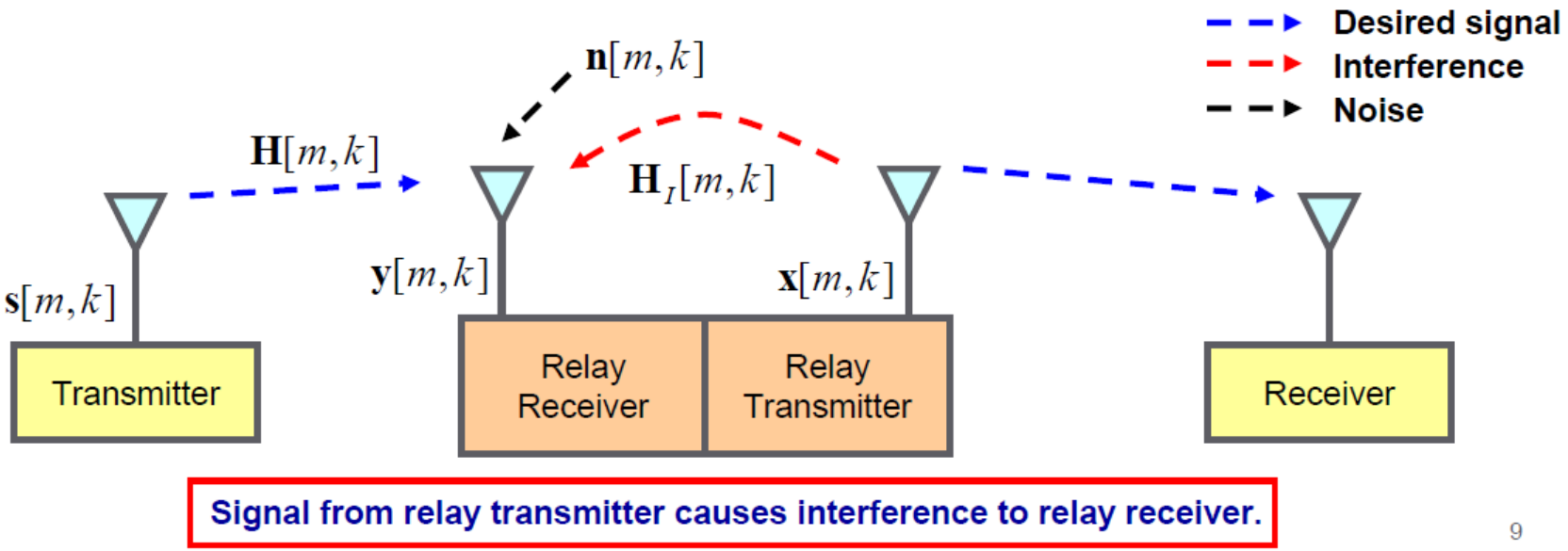
- Refer to IEEE C802.16m-10/0202.

Appendix A:

Combating Self-interference in STR Relaying on the Same Carrier

Understanding What Causes Self-interference

- Self-interference
  - Relay TX antenna and relay RX antenna is closely located.
  - In STR relaying, feedback interference from relay TX antenna can be significantly larger than the desired signal.
  - Because the relative position of relay TX antenna and relay RX antenna is fixed, the channel is expected to be a slowly varying channel.



Combating Self-interference (1/4)

- Means to reduce interference from relay TX to relay RX
  1) Isolation between relay TX antenna and relay RX antenna
  2) Interference cancellation

Combating Self-interference (2/4)

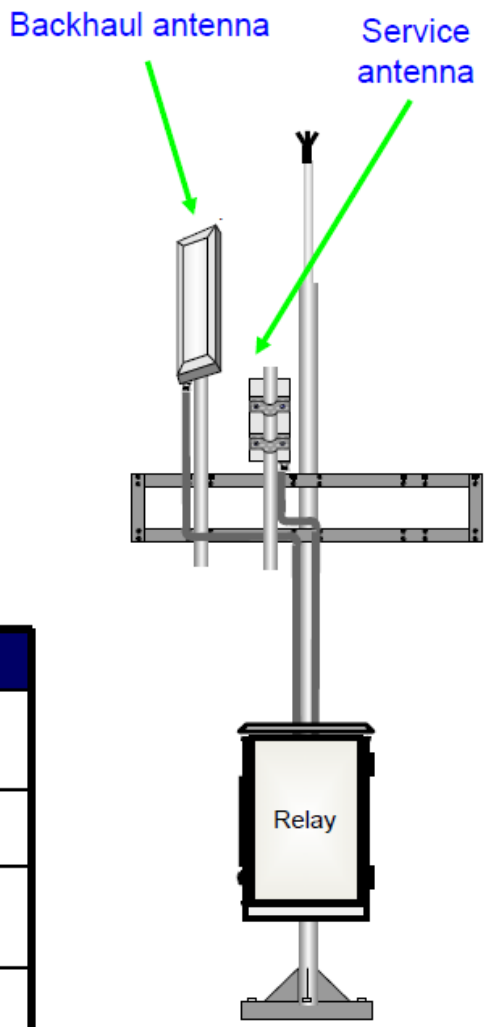
- How much isolation can be achieved?

  → Upwards of 80 dB

  – Total isolation = G_t + (free space loss) + G_r
    - G_t : Gain of the TX antenna toward RX antenna
    - G_r : Gain of the RX antenna toward TX antenna
    - Free-space loss : 32.44 + 20*log10(distance(km)) + 20*log10(frequency(MHz))(dB)

  – Typical example for downlink case

Item	Isolation	Remark
Gt	31 dB	SP antenna (14 dBi) F/B (front-to-back) ratio: 45 dB
Gr	6 dB +	Sector antenna (19 dBi)
Free-space loss	43.2 dB	Vertical distance: 1.5m Frequency: 2,300 MHz
Total	80.2 dB +	



Combating Self-interference (3/4)

- Principle of self-interference cancellation
  - Received signal at relay receiver

$$\mathbf{y}[m,k] = \mathbf{H}[m,k]\sqrt{P_s}\,\mathbf{s}[m,k] + \mathbf{H}_I[m,k]\sqrt{P_I}\,\mathbf{x}[m,k] + \sqrt{P_n}\,\mathbf{n}[m,k]$$

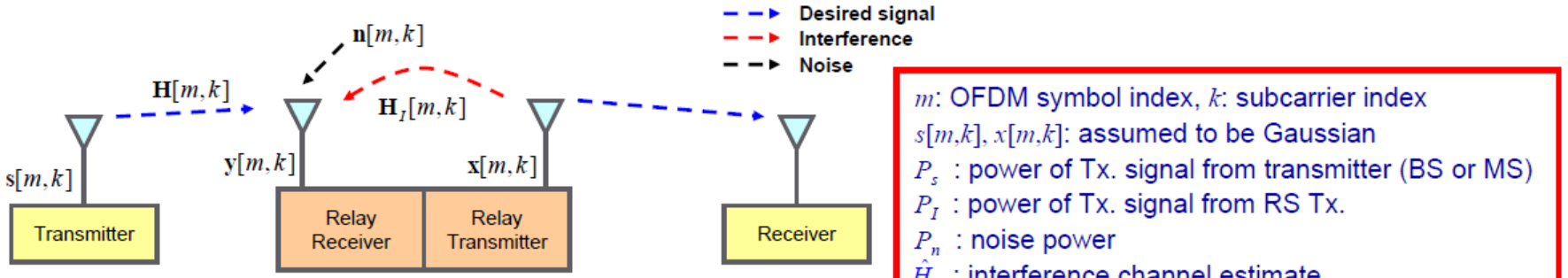
$$\left(E\{\mathbf{s}\mathbf{s}^H\} = \mathbf{I},\ E\{\mathbf{x}\mathbf{x}^H\} = \mathbf{I},\ E\{\mathbf{n}\mathbf{n}^H\} = \mathbf{I}\right)$$

  - Self-interference cancellation

$$\mathbf{y}[m,k] - \hat{\mathbf{H}}_I[m,k]\sqrt{P_I}\,\mathbf{x}[m,k]$$

$$= \mathbf{H}[m,k]\sqrt{P_s}\,\mathbf{s}[m,k] + (\mathbf{H}_I[m,k] - \hat{\mathbf{H}}_I[m,k])\sqrt{P_I}\,\mathbf{x}[m,k] + \sqrt{P_n}\,\mathbf{n}[m,k]$$

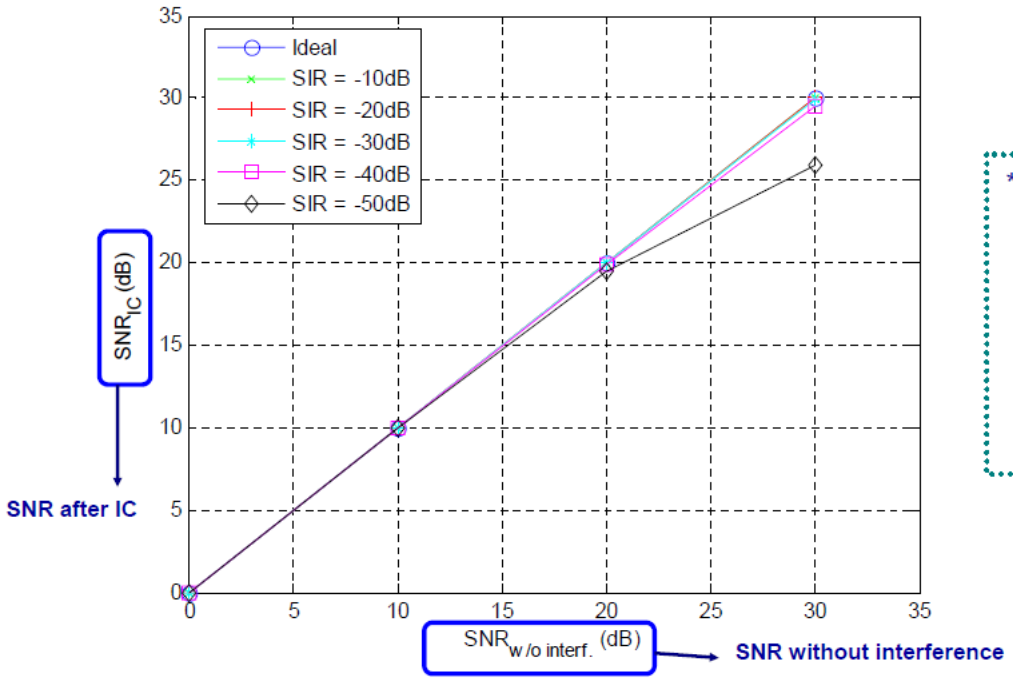
$$\approx \mathbf{H}[m,k]\sqrt{P_s}\,\mathbf{s}[m,k] + \sqrt{P_n}\,\mathbf{n}[m,k]$$



m: OFDM symbol index, k: subcarrier index
$s[m,k]$, $x[m,k]$: assumed to be Gaussian
P_s : power of Tx. signal from transmitter (BS or MS)
P_I : power of Tx. signal from RS Tx.
P_n : noise power
$\hat{H}$: interference channel estimate

Combating Self-interference (4/4)

- What can be achieved by interference cancellation (IC) ?
  - Up to SIR of -40 dB, high degree of cancellation can be achieved.



* Simulation Set-up
  - Assumed static relay
    → Used Ped. A channel model
    → Normalized Doppler freq. 5 Hz is considered to account for environmental variation
  - Floating-point simulation

1) SIR: ratio between **desired signal power** to **inter-antenna interference power** at the relay receiver (ignoring noise)
2) SNR: ratio between **desired signal power** to **noise** at the relay receiver (ignoring inter-antenna interference from relay transmitter)

Putting Isolation and Cancellation Together

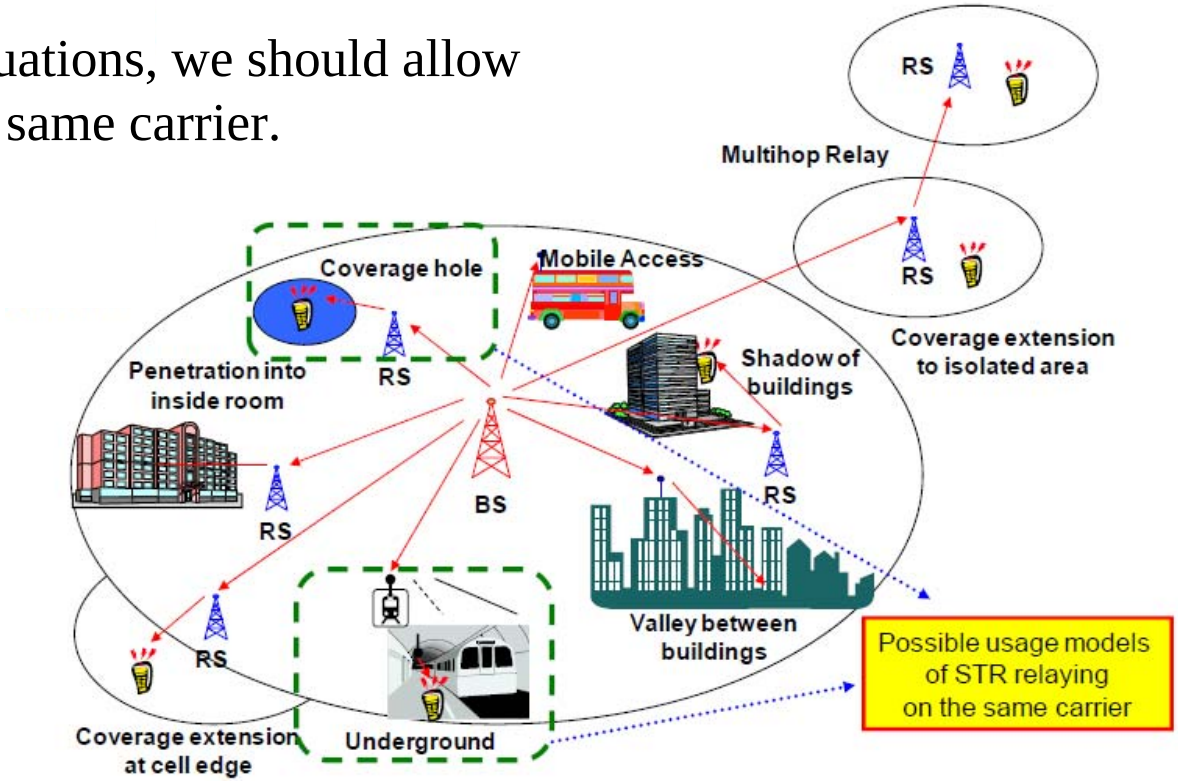
- Relation between relay transmission power and SIR
  - Given relay TX power and isolation between relay TX and RX antennas, SIR value can be found using the previous figures.
  - With calculated SIR and SNR at relay RX, the difference between $SNR_{w/o\ interf.}$ and SNR_{IC} can be found using the previous figure.
  - Up to SIR of -40 dB, there is no noticeable SNR degradation due to residual interference after interference cancellation.

Relay Tx. Power	Isolation	Relay Tx. Power after Isolation	BS Signal Power @ Relay Rx	Distance from BS 1)	SIR
30dBm	80dB	-50dBm	-60dBm	~ 200m	-10dB
			-70dBm	~ 500m	-20dB
			-80dBm	~ 1300m	-30dB
			-90dBm	1300m +	-40dB

1) Assumes WINNER B5a channel model (similar to LOS channel of 16j) with fading margin of 10 dB.

What the Results Say (1/2)

- Some situations naturally provide isolation
  - e.g. underground and coverage hole.
    - Some operators may want to operate this usage scenario.
  - At least for those situations, we should allow STR relaying on the same carrier.



What the Results Say (2/2)

- In some situations, reasonable isolation may be possible, and more can be done by using interference cancellation.
  - e.g. when the relay TX and RX antennas are sufficiently separated with appropriate antenna arrangement.
  - The graph shows that high degree of cancellation can also be achieved.

Appendix B:

Comparison between ICS Repeater and STR Relay on the Same Carrier

Interference Cancellation System (ICS) Repeater

- The concept of ICS
  1) Estimate feedback channel using transmitted and received signal
  2) Regenerate feedback signal using transmission signal and estimated feedback channel information
  3) Extract desired signal by subtraction regenerated feedback signal from received signal

- Many ICS repeater products for Mobile-WiMAX have been commercialized.
  - e.g. ubiqam, Airpoint, etc.

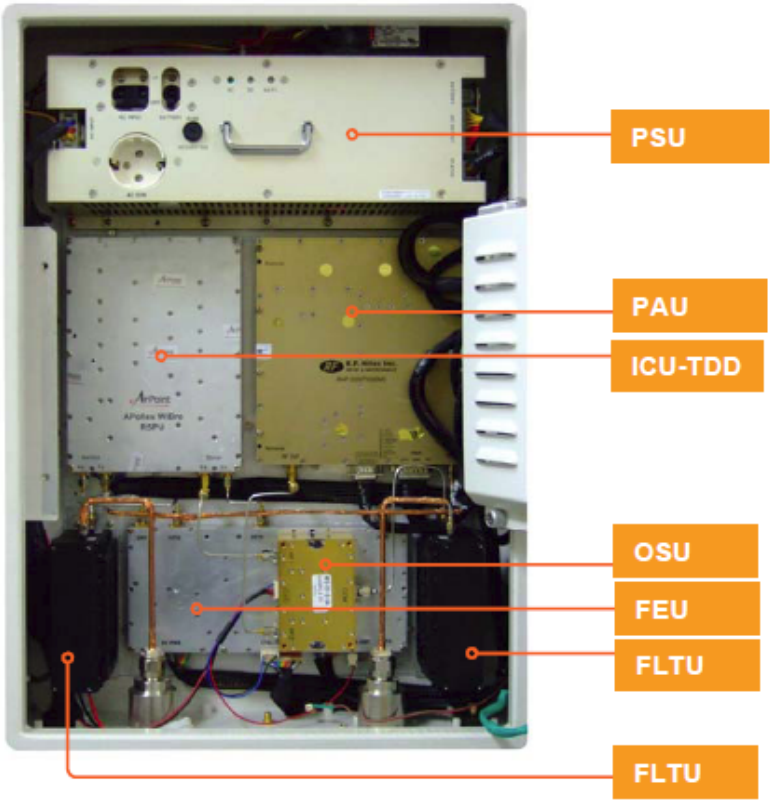
ubiqam's Product

Description	UBQ27xx
Operation Mode	• Decode and Forward (Relay) • Amplify and Forward (Repeater)
Duplexing	TDD or H-FDD
Frequency bands	• UBQ2725: 2.5-2.7GHz • UBQ2735: 3.3-3.8 GHz
Tx Power	27dBm (0.5W)
STR™ Performance	• 40 dB gain over isolation @ 64 QAM (Relay Mode) • 15 dB gain over isolation (Repeater mode)
MIMO Support	• Access: 2 RX path ; 1 TX path (2 TX path optional) • Backhaul: 2 RX path ; 1 TX path (2 TX path optional)
Gain & AGC Range	80~30dB (Repeater mode)
Total System Delay	≤ 5~8us (Repeater mode)
RF Performance	Transmit/Receive EVM > 32dB Adjacent channel rejection > 22dB Alternate channel rejection > 43 dB
Throughput	Maximum theoretical throughput >35 Mbps (total DL + UL)
Backhaul (Subscriber) Baseband	802.16e (WiMAX Forum® Wave-II Certified)
Interfaces	• Ethernet: RJ-45 100Base-T • Antenna: 4 X N-Type

☑ Refer to the following web site : www.ubiqam.com

Airpoint's Product

WEWE40
Wave-Enhancer for Wibro Enjoy



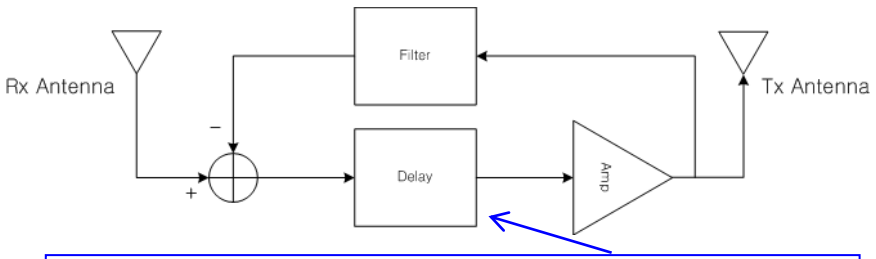
Mobile-WiMAX ICS Repeater Specification

Frequency		2331.5MHz ~ 2358.5MHz(TDD)
Output Power	FWD	40dBm/Total
	RVS	23dBm/Total
System Gain	FWD	65dB ~ 95dB(30dB)
	RVS	65dB ~ 95dB(30dB)
System Delay		3.5us
EVM(64QAM) Gain = Isol + 5dB		5%
Noise Figure (RVS)		5dB
Max Operating Gain		Isolation + 5dB Isolation + 15dB (LAB)
Cancellation Range		6us
Size / Weight		400(W)x600(H)x240(D) / 38Kg
Power Consumption		350W Max
Reference site		Test site in Seoul

☑ Refer to the following web site : www.airpointglobal.com

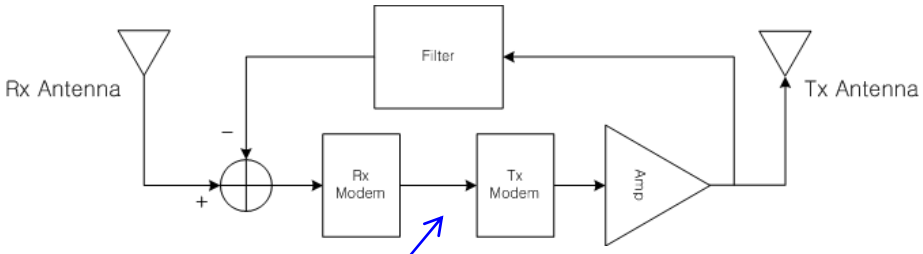
Comparison between ICS Repeater and STR Relay on the Same Carrier

ICS Repeater



Output signal of ICS repeater : Delayed input signal

STR Relay on the same carrier



Output signal of STR relay : Regenerated signal

- Difference between ICS repeater and STR relay
  - An ICS repeater amplifies and forwards the delayed input signal, whereas a STR relay sends the regenerated signal in Tx. modem.
- STR relay has better IC performance than ICS repeater.
  - It is because STR relay can utilize the whole signal transmitted from it for channel estimation between its transmitter and receiver, which is used for interference cancellation.
  - In ICS repeater, only pilot signal can be utilized for channel estimation.

  → IC accuracy of STR relay is better than that of ICS repeater.
  - Example: According to ubiqam's product,
    - 40 dB gain over isolation @ 64 QAM (Relay mode)
    - 15 dB gain over isolation (Repeater mode)

☑ IC (Interference Cancellation)