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APPLICATION OF MULTIHOP RELAY FOR PERFOMANCE ENHANCEMENT OF AeroMACS NETWORKS

Behnam Kamali, Mercer University School of Engineering

Jeffrey D. Wilson, NASA Glenn Research Center

Robert J. Kerczewski, NASA Glenn Research Center

Abstract

A new transmission technology, based on IEEE 802.16-2009 (WiMAX), is currently being developed for airport surface communications. A C-band spectrum allocation at 5091-5150 MHz has been created by ITU to carry this application. The proposed technology, known as AeroMACS, will be used to support fixed and mobile ground to ground applications and services. This article proposes and demonstrates that IEEE 802.16j-amendment-based WiMAX is most feasible for AeroMACS applications. This amendment introduces multihop relay as an optional deployment that may be used to provide additional coverage and/ or enhance the capacity of the network. Particular airport surface radio coverage situations for which IEEE 802.16-2009-WiMAX provides resolutions that are inefficient, costly, or excessively power consuming are discussed. In all these cases, it is argued that 16j technology offers a much better alternative. A major concern about deployment of AeroMACS is interference to co-allocated applications such as the Mobile Satellite Service (MSS) feeder link. Our initial simulation results suggest that no additional interference to MSS feeder link is caused by deployment of IEEE 802.16j-based AeroMACS.

Presentation Outline

- IEEE 802.16j Amendment
- Relays: General Benefits and Usage Scenarios
- Multihop Relay Configuration for AeroMACS
- Benefits of Multihop Relay configuration for AeroMACS
- The AeroMACS Test bed; An Example for Multihop Relay Application
- IEEE-802.16j-Based AeroMACS Interference to MSS
- Concluding Remarks

IEEE 802.16j Amendment

This amendment updates and expands IEEE Std 802.16, specifying OFDMA physical layer and medium access control layer enhancements to IEEE Std 802.16 for licensed bands to enable the operation of relay stations. Subscriber station specifications are not changed. The current applicable version of IEEE Std 802.16 is IEEE Std 802.16-2009, as amended by IEEE 802.16j-2009.

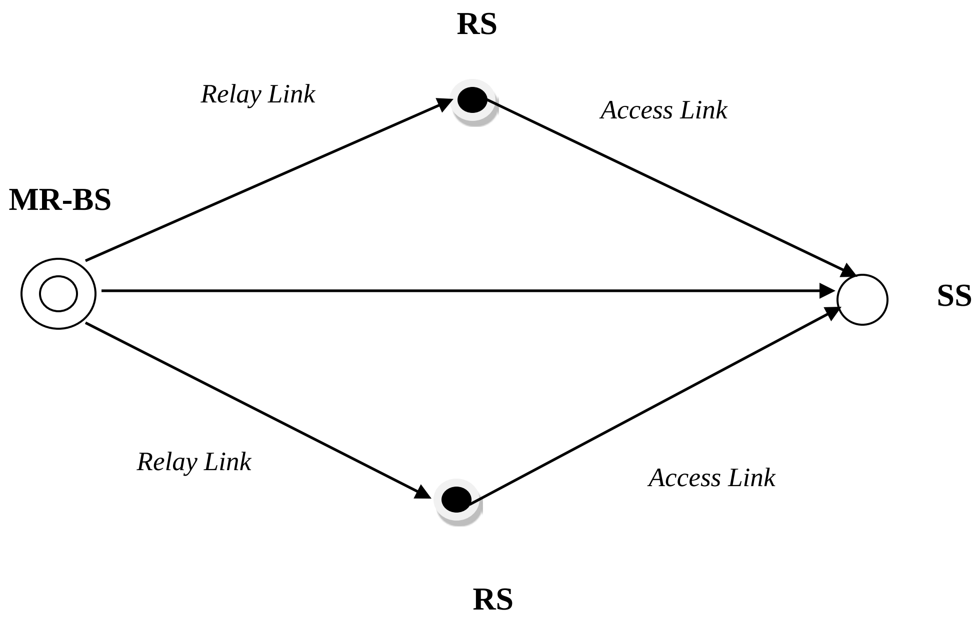
The amendment introduces multihop relay (MR) as an optional deployment that may be used to provide additional radio coverage or provide improved performance/ enhanced capacity in an access network. In relay-augmented networks, the BS may be replaced by a multihop relay BS, MR-BS, and as many RSs as needed. Traffic and signaling between the SS/MS and MR-BS may be direct, or may be relayed by the RS thereby extending the coverage and enhancing performance of the system in areas where RSs are deployed.

A simple relay network consisting of two relay stations

Traffic and signaling between MR-BS and SS may be routed through "*access RSs*" or via a direct link between MR-BS and the SS.

The physical channel between the MR-BS and a relay is called *relay link*, and the channel between an access relay and a SS is termed as *access link*.

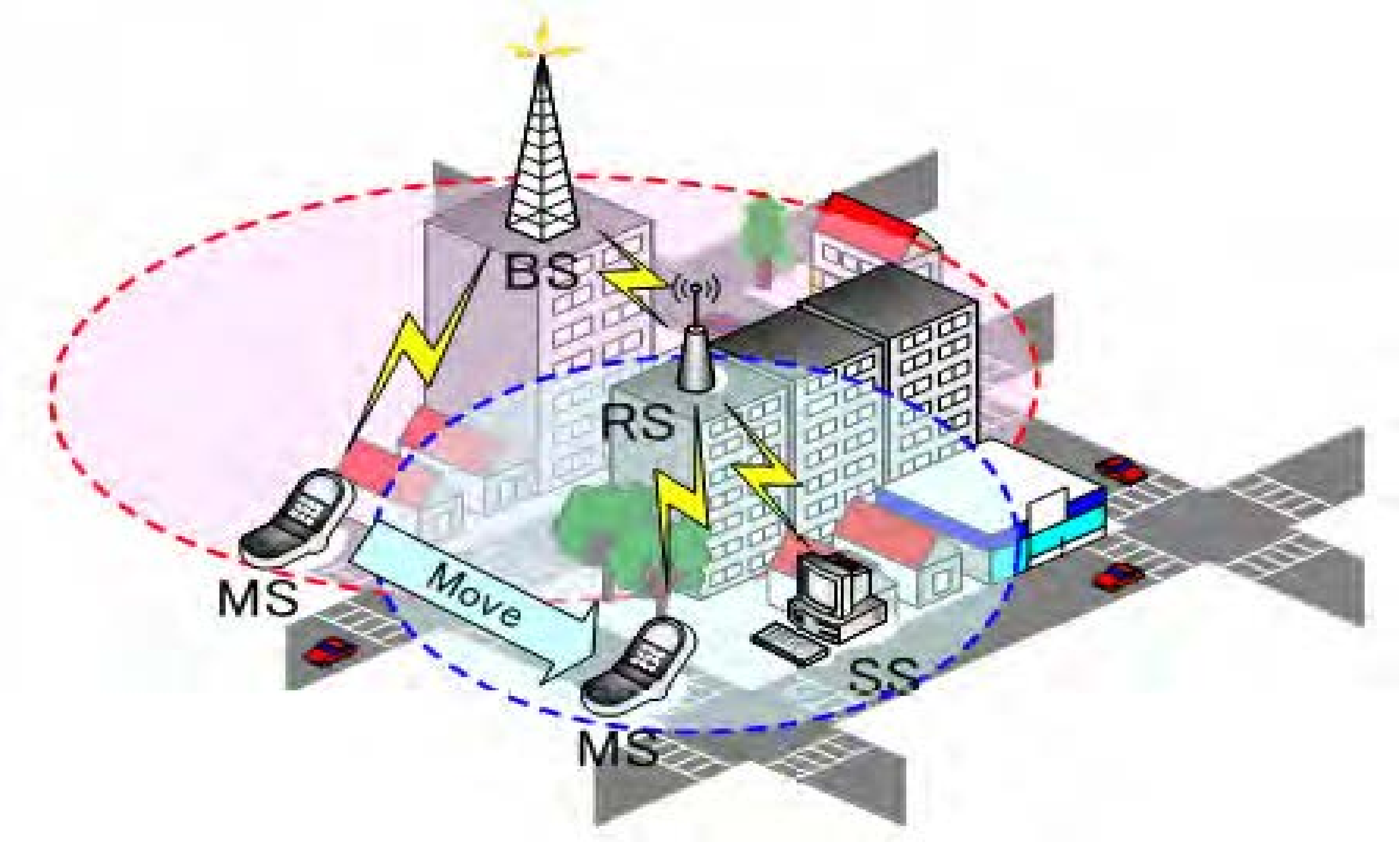
The protocols on the access link; including those related to mobility, remains the same as the ones in IEEE 802.16-2009, however, new functionalities are specified on relay links to support the multi hop features.



Relays: Benefits and Usage Scenario

- Extension of radio coverage into areas severely shadowed by buildings or natural obstacles.
- Enhancement of coverage and throughput on or beyond WiMAX cell footprint boundary.
- Improvement in radio coverage inside a building or a high rise complex.
- Providing coverage in a dense urban area.
- Providing temporary coverage and temporary capacity upgrade.
- Increasing network capacity to support intense-usage areas; “hot spots”.
- Resolving special coverage challenges; “coverage hole filling”.
- Extension of radio access to moving vehicles such as buses, trains, aircraft.
- Providing radio coverage over roads and tunnels

Multihop Relay-Augmented WiMAX Network



Multihop Relay Configuration for AeroMACS

- It is stipulated that ,other than some issues related to general application of IEEE 802.16j technology to any scenario, there are no additional technical challenges in application of IEEE 802.16j-based WiMAX to AeroMACS.

- The application of multihop relay configuration enables a reduction in path loss, and therefore a link budget "gain" is resulted. This multihop gain can be translated into one or more of the following system enhancements for AeroMACS:

  – *Radio outreach extension*

  – *Improvement in throughput and network capacity*

  – *Reduction in transmit power which is one of the primary concerns in AeroMACS application regarding the issue of interference into co-allocated applications*

Benefits of Multihop Relay configuration for AeroMACS

- When a portion of an airport is significantly shadowed by a new obstacle, such as a building constructed for a new terminal, a 16j-defined relay can be added to the airport network to provide higher capacity and acceptable QoS to the shadowed area.

- Adding a relay to an already established network does not require network reconfiguration and radio resource reallocation. The alternatives that IEEE 802.16-2009 offers are either the addition of another BS to the system which requires reallocation of resources, or an increase in output power of other BSs.

- Short-term coverage for areas temporarily blocked , or coverage for areas on a temporary basis due to special circumstances may be readily provided by a relay.

- If a station is outside of the airport area that needs connection to the AeroMACS network, an RS (as opposed to a BS) can be used to establish the connection.

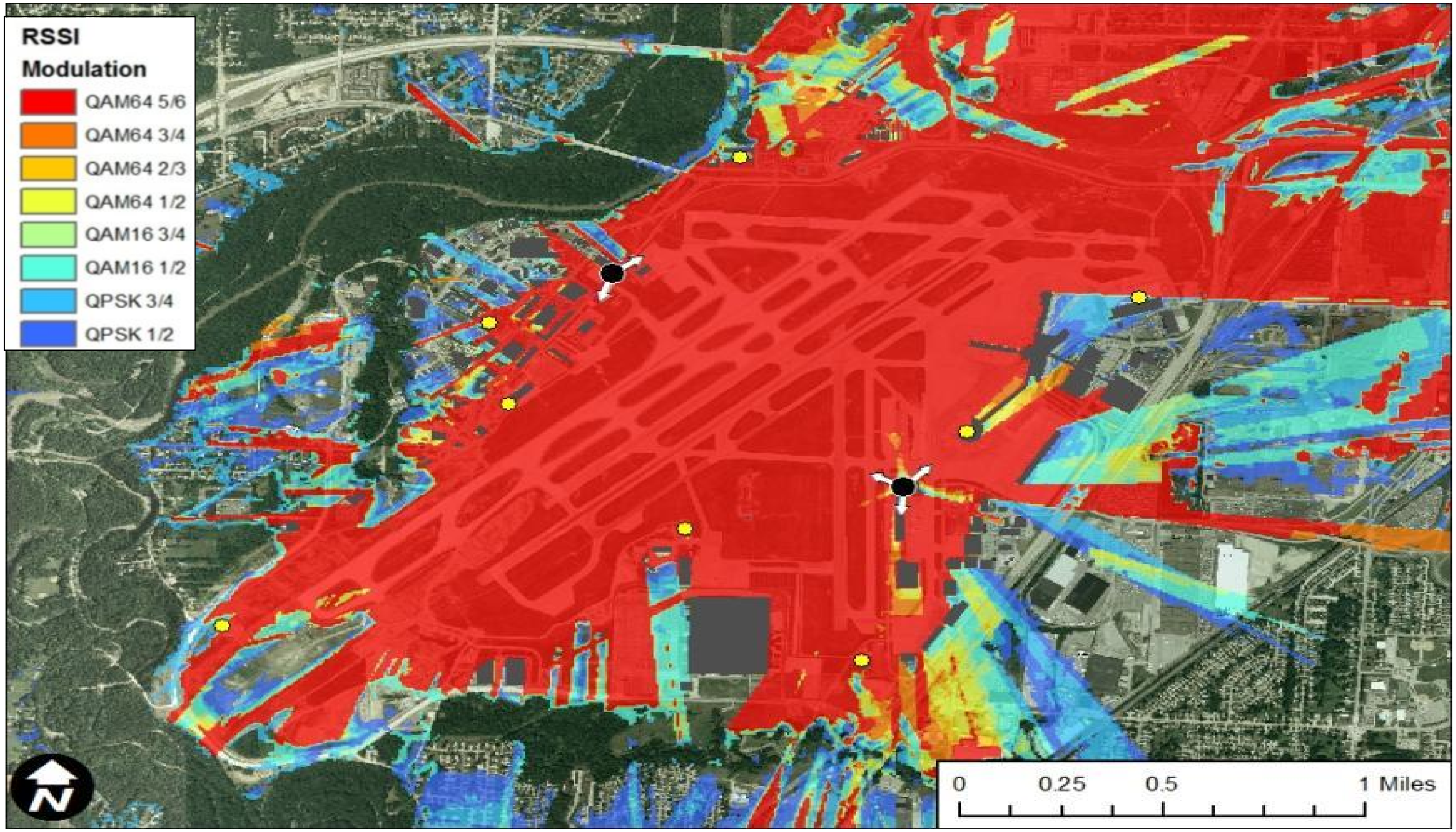
- Relays may be also used to provide coverage to other airport assets such as lighting system, navigational aid, weather sensors, wake sleep sensor, and etc.

WiMAX Physical Data Rates

- *PUSC*
- *Frame Duration: 5 ms*
- *48 OFDM Symbols/frame*
- *44 OFDM data Symbols/frame*

Modulation	CTC Rate/ RepCode	DL Rate Mbps 5 MHz	UL Rate Mbps 5 MHz	DL Rate Mbps 10 MHz	UL Rate Mbps 10 MHz
QPSK	1/2 , 6X	0.53	0.38	1.06	0.78
QPSK	1/2 , 4X	0.79	0.57	1.58	1.18
QPSK	1/2 , 2X	1.58	1.14	3.17	2.35
QPSK	1/2 , 1X	3.17	2.28	6.34	4.70
QPSK	3/4	4.75	3.43	9.50	7.06
16QAM	1/2	6.34	4.57	12.67	9.41
16QAM	3/4	9.50	6.85	19.01	14.11
64QAM	1/2	9.50	6.85	19.01	14.11
64QAM	2/3	12.67	9.14	25.34	18.82
64QAM	3/4	14.26	10.28	28.51	21.17
64QAM	5/6	15.84	11.42	31.68	23.52

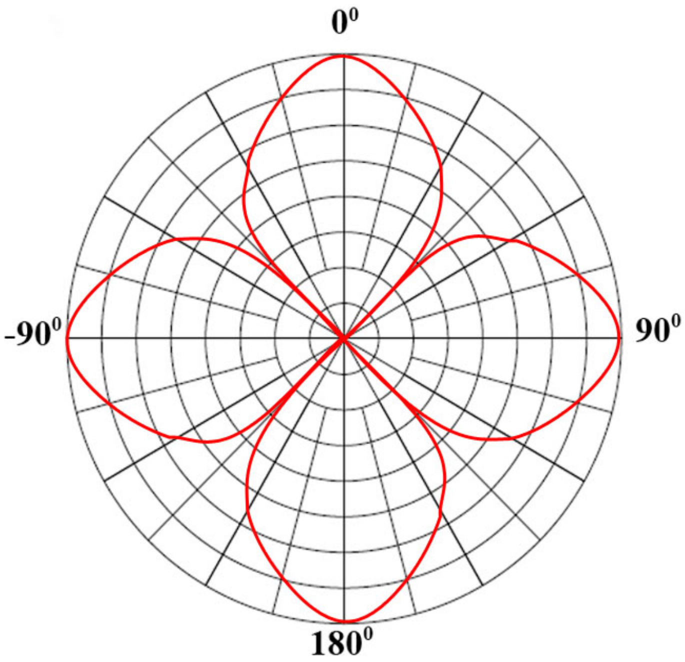
Receive Signal Strength Indicator (RSSI); Cleveland Hopkins Airport



IEEE-802.16j-Based AeroMACS Interference to MSS

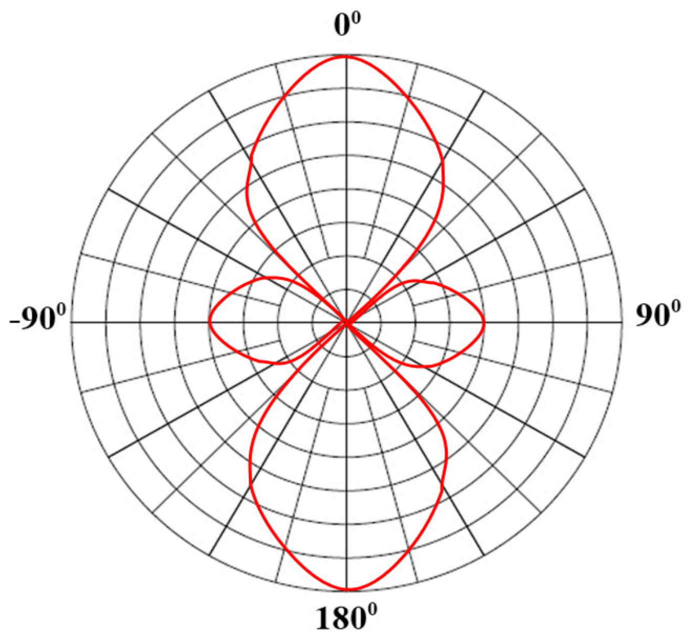
- A major concern about deployment of AeroMACS over the 5091-5150 MHz band is interference to co-allocated applications such as the Mobile Satellite Service (MSS) feeder link. This limits the power levels that are allowed for AeroMACS networks. Analytical methods and computer modeling have been employed to test and measure the level of interference posed by AeroMACS networks to co-allocated applications. At NASA Glenn Research Center the software program Visualyse Professional is being utilized to estimate the limitations of AeroMACS transmitter output power levels in order to avoid excessive interference with MSS signals.

- To compare interference by IEEE 802.16-2009-based AeroMACS with that of IEEE 802.16j-based AeroMACS to MSS, one needs to set up two models, an all-BS airport network and a network with mixed MR-BS and RSs. Visualyse Professional has been used to make the comparison. Six different scenarios have been modeled and 10 simulation runs have been conducted for each scenario.



An all-BS network with four BS antenna beams oriented at 0^0, 90^0, 180^0, and -90^0

This case closely approximate an omnidirectional gain pattern, the total radiated power is 400 mW

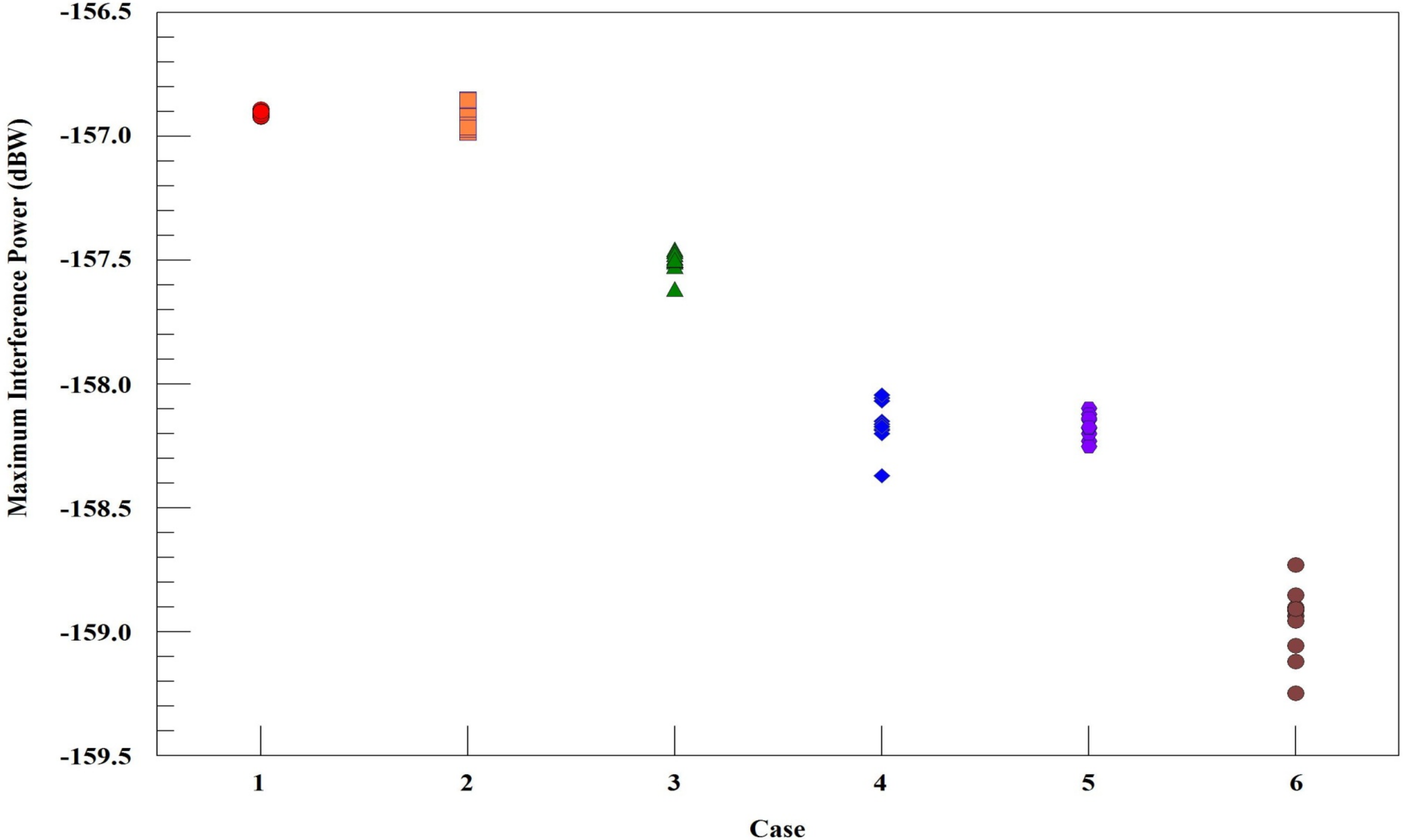


A mixed BS-RS network with two BS antenna beams oriented at 0^0 and 180^0 and with two RS beams oriented at 90^0 and -90^0

The total radiated power is decreased to 300 mW in in this Case. There are two BS beams and two RS beams. The maximum interference power decreases as expected.

Aggregate interference power posed by all 497 US towered airports into MSS for various AeroMACS configurations

Case/ Output Power	Configuration	Average Interference Power (dBW)	Standard Deviation (dBW)	MIN (dBW)	MAX (dBW)	Range (dBW)
Case 1 300 m W	*Three BSs, or a single BS with a 3-sector antenna: (0° , 120°, -120°)*	-158.158	0.094	-158.370	-158.044	0.326
Case 2 400 m W	*Four BSs, or a single BS with a 4-sector antenna (0° , 90°, 180°, -90°)*	-156.907	0.010	-156.923	-156.891	0.032
Case 3 400 m W	*Three BSs with two RSs, or a single BS with a 3-sector antenna(0° , 90°, 180°) and a single RS with a 2-sector antenna (135°, -135°)*	-156.915	0.053	-156.987	-156.851	0.136
Case 4 300 m W	*Two BSs and two RSs , or a single BS with a 2-sector antenna(0° , 180°) and a single RS with a 2-sector antenna(90°, -90°)*	-158.171	0.048	-158.253	-158.099	0.154
Case 5 350 m W	*Three BSs and a single RS, or a single BS with a 3-sector antenna(0°, 90°, 180°) and a single RS with directive antenna (-90°)*	-157.502	0.045	-157.615	-157.456	0.159
Case 6 250 m W	*Two BSs and a single RS, or a single BS a 2-sector antenna (0°, 180°)* with a single RS with directive antenna *(90°)*	-158.962	0.146	-159.249	-158.731	0.518


Maximum Interference Power (dBW)
-156.5
-157.0
-157.5
-158.0
-158.5
-159.0
-159.5
1
2
3
4
5
6
Case

Concluding Remarks

- For AeroMACS, IEEE 802.16j-based technology provides feasible radio coverage at airport surface for situations in which the IEEE 802.16-2009-WiMAX system either fails to offer a viable solution, or the resolution it provides is inefficient, costly, or excessively power consuming. In all these cases, it is argued that 16j technology offers a much better alternative.

- The most recent AeroMACS profile indicates no additional technical challenges exist for application of IEEE 802.16j-based WiMAX to AeroMACS. However, a thorough examination of the present and future drafts of the AeroMACS profile is recommended. This is to ensure that there are no insurmountable technical challenges for application of 16j to AeroMACS.

- The application of multihop relay configuration enables a reduction in path loss, and therefore a link budget "gain" is resulted.

- Our initial simulation results demonstrate that no additional interference to the MSS feeder link is caused by deployment of IEEE 802.16j-based AeroMACS.