Attenuation of Radio Frequency Signals by Portable and Built-in-place Refuge Alternatives

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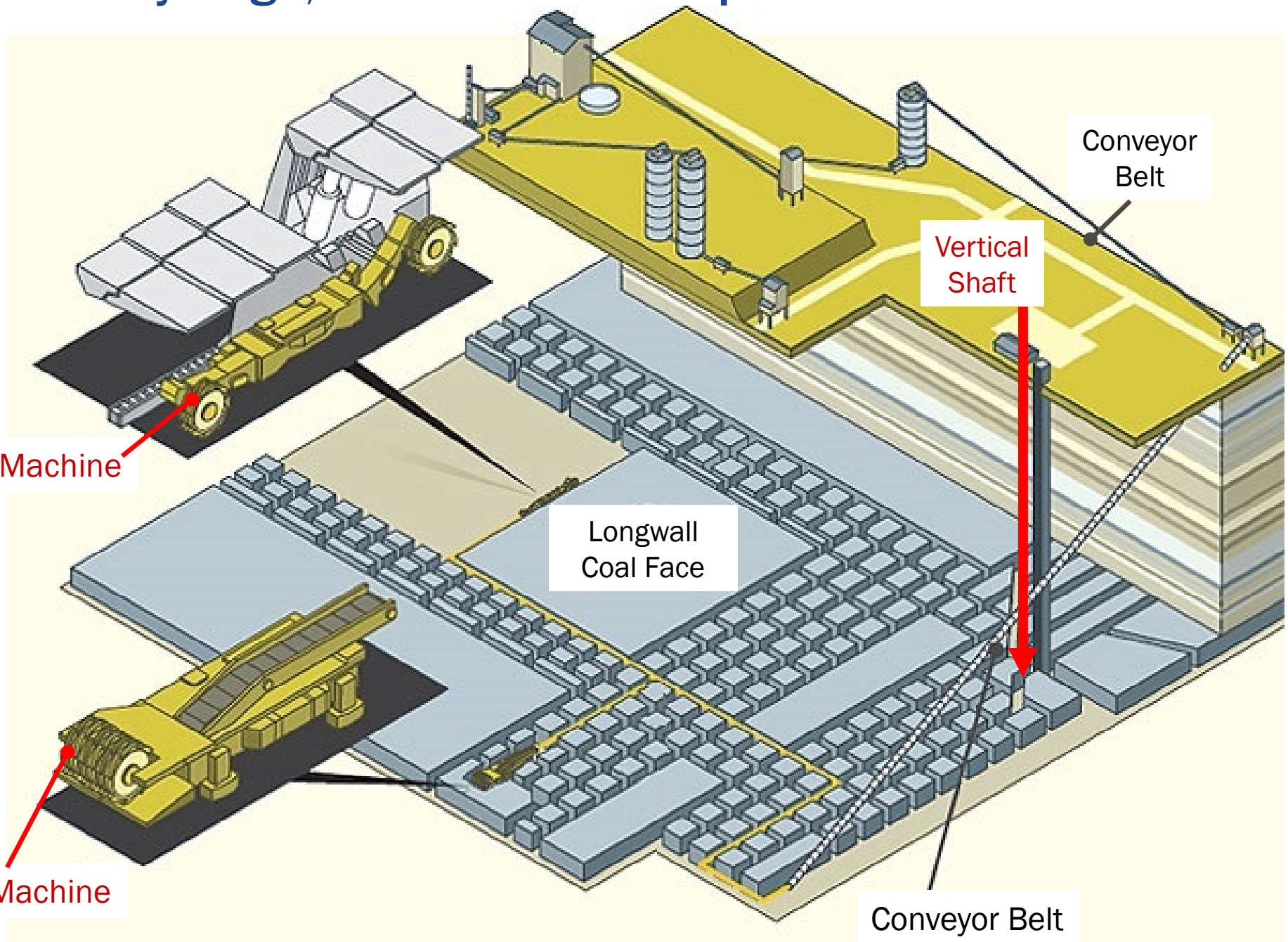
Outline

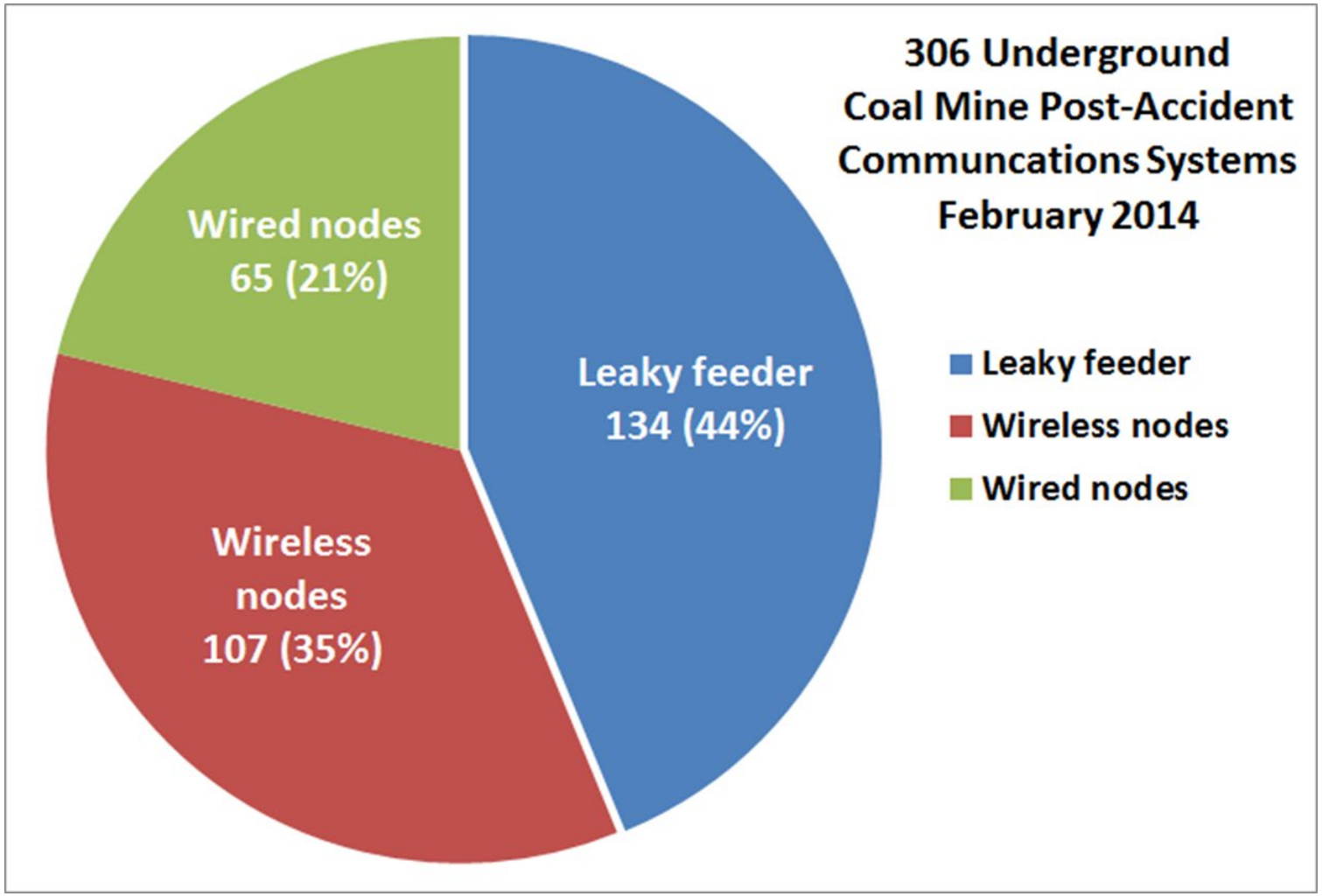
1. What are post-accident communication systems?
2. Underground coal mines refuge alternatives (RAs)
3. RA communications
4. Summary

Mines can be very large, confined and deep below the surface



Coal mine entries act as a “waveguide”

In 2014, NIOSH conducted a review of coal mine emergency response plans



- 13 different leaky feeder or node-based post-accident communications systems

In 2014, 13 coal mine post-accident communications systems

All names taken from the manufacturer's website and/or ERPs		
Manufacturer	**ERP**	
Full Name	**Abbrev.**	**System name(s)**
Leaky Feeder Systems		
Becker Varis	Varis	Smart Com 150/450
Kutta Radios	Kutta	DRUM 100S
Mine Radio Systems*	MRS	Flexcom
MineCom*	MineCom	MCA 1000/2000
Tunnel Radio of America	TRA	Ultracomm/MineAx
Wired Node-Based Systems		
American Mine Research	AMR	Mine Net
Matrix Design Group	Matrix	METS 1.0/2.1
Mine Site Technologies	MST	IMPACT
Northern Light Tech.	NLT	InfoMine
Wireless Node-Based Systems		
Active Control Technology	ACT	Active Mine
Innovative Wireless Tech.	IWT	Sentinel/Accolade
Strata Products Worldwide	Strata	CommTrac
Venture Design Group	Venture	MineTracer
*MineCom and Mine Radio Systems are now a part of PBE Group		

2 different types of high frequency post-accident communications systems

1. Leaky feeder systems: cable acts as transmission line and antenna

2. Node-based systems: communication network of processor-based devices

NIOSH conducted signal attenuation measurements underground on 3 types of RAs

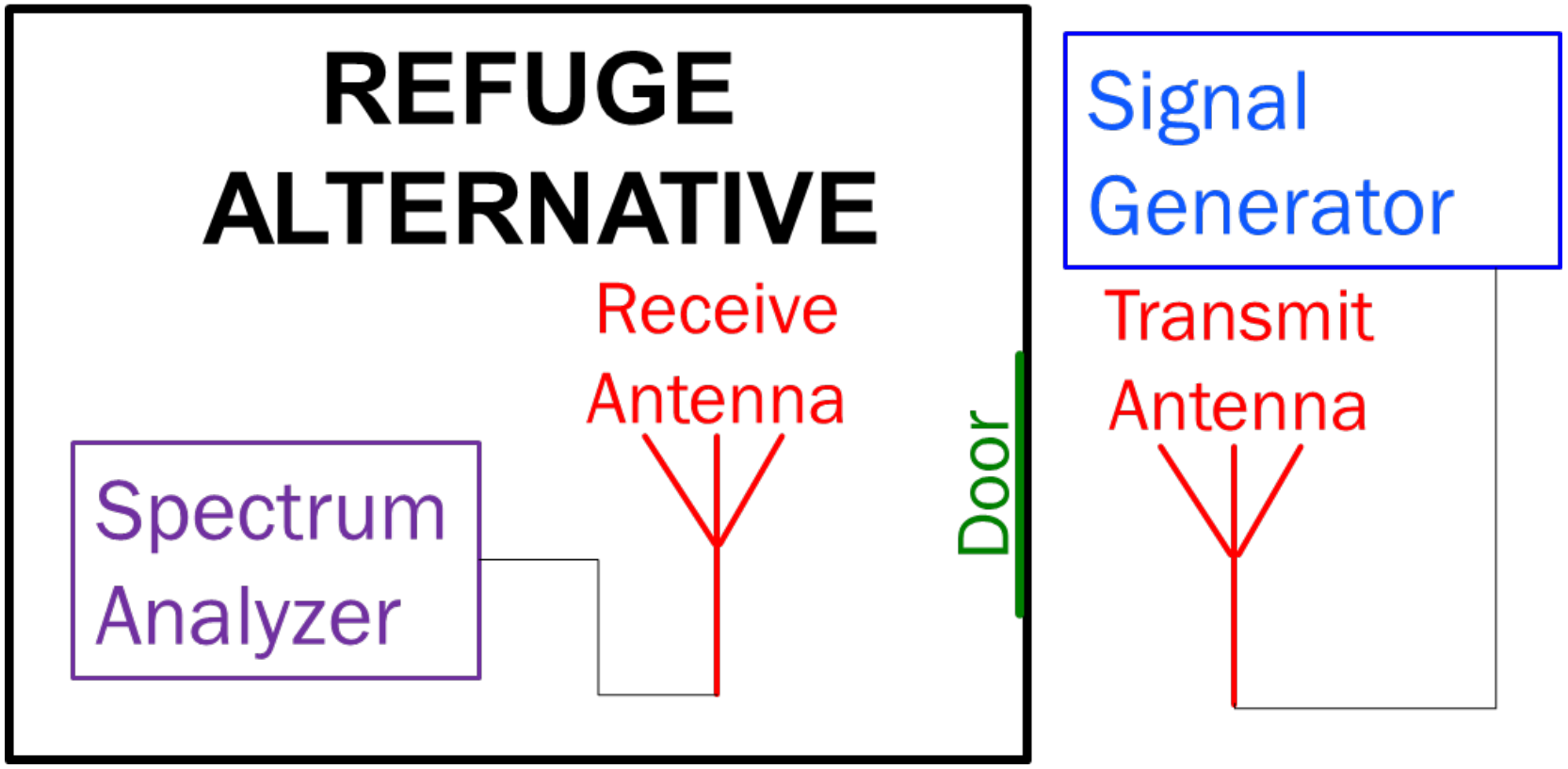
Three types of refuge alternatives are used in underground US coal mines for up to 96 hours

- Tent-type portable RA
  - Inflatable tent contained within a rigid metal box
  - Provide oxygen via compressed oxygen cylinders
  - Largest holds up to 36 miners

- Rigid portable RA
  - Rigid metal structure
  - Provide oxygen via compressed oxygen cylinders
  - Generally, hold fewer miners because of their size limitation

- Built-in-place (BIP) RA
  - Permanent structures
  - All BIP RAs in the US are outby and use boreholes or compressed air lines to provide breathable air
  - Can be sized for a large number of miners

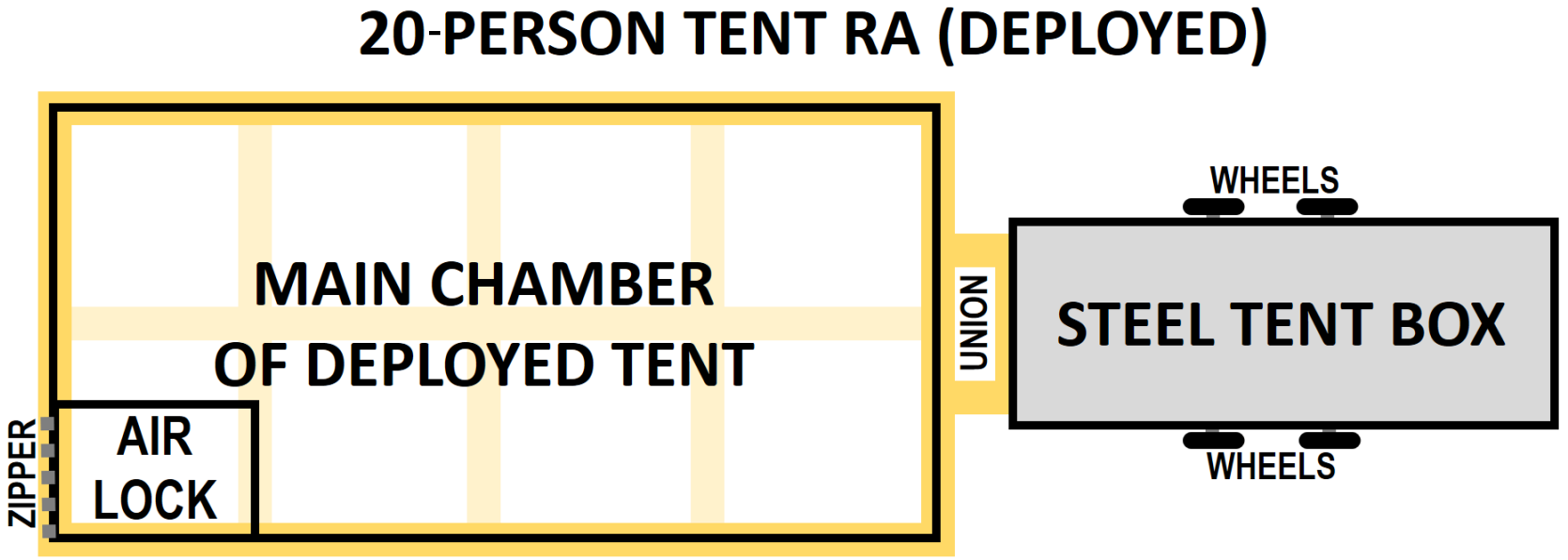
General test setup in the Experimental Mine



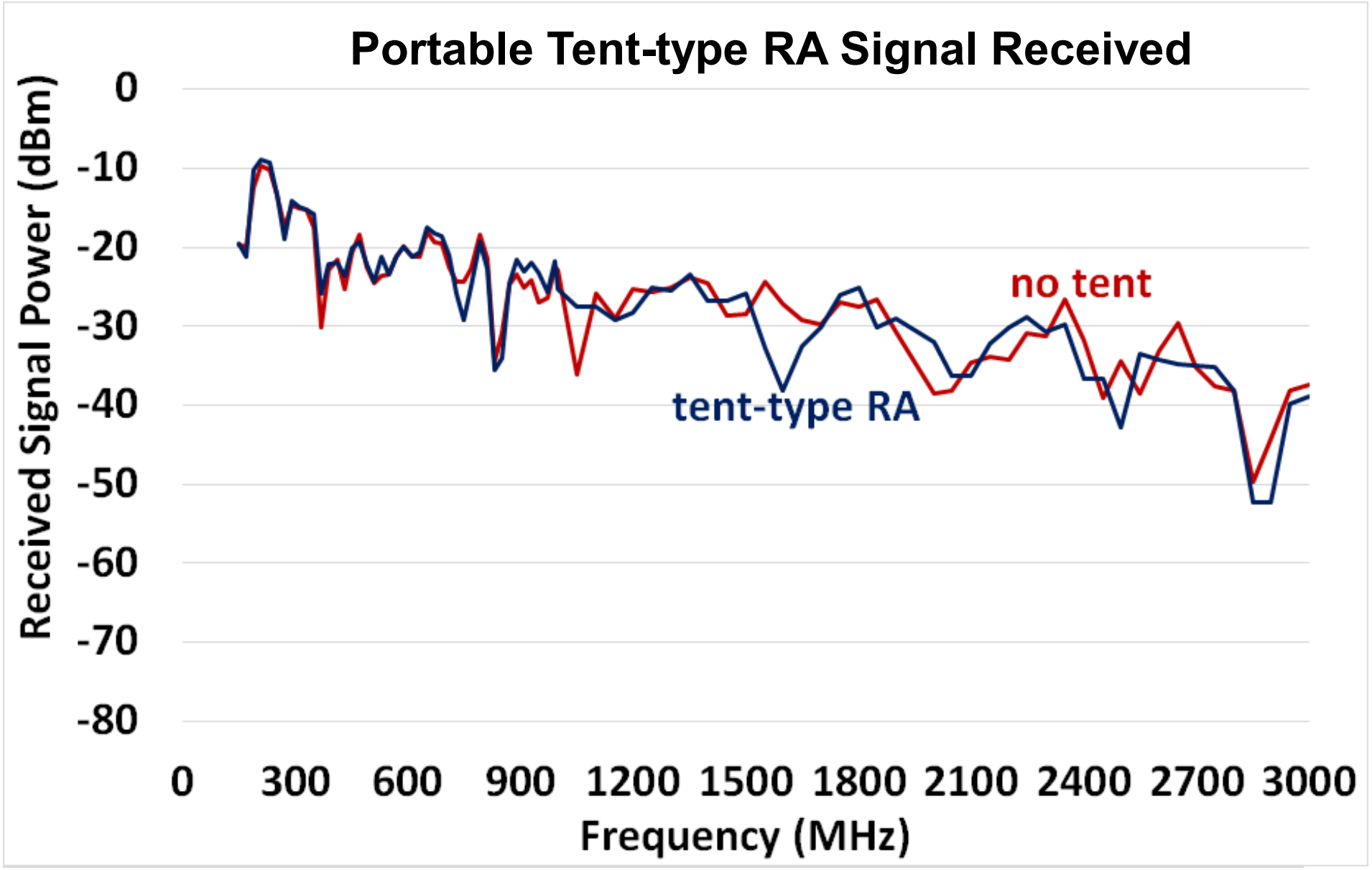
NIOSH performed signal attenuation measurements on a tent-type RA

Tent-type RA, 20-person

- 7700 kg
- Box: 4.5 m long by 1.7 m wide by 1 m high
- Tent: 7.3 m long by 3.5 m wide by 1.7 m high
- PVC (polyvinyl chloride) coated fabric walls with air-filled neoprene support tubes



Little difference in signal with or without the tent-type RA

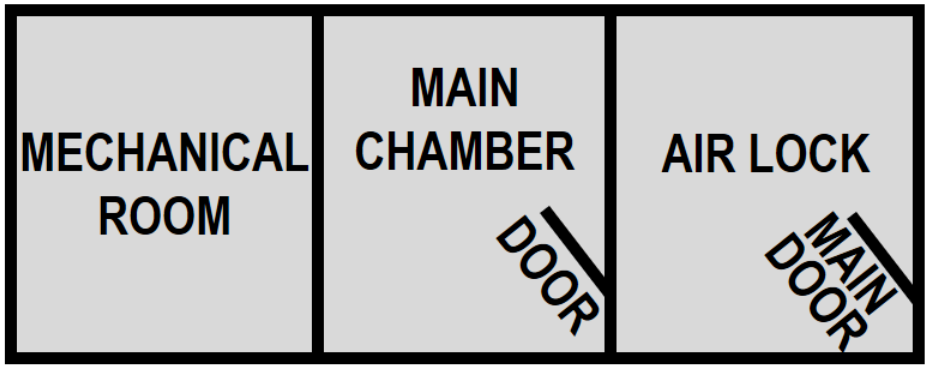


NIOSH performed signal attenuation measurements on a metal-type RA

Metal-type, 6-person

- 5000 kg
- 5.25 m long by 2 m wide by 1.4 m high
- constructed of steel plates welded to a tubular steel frame

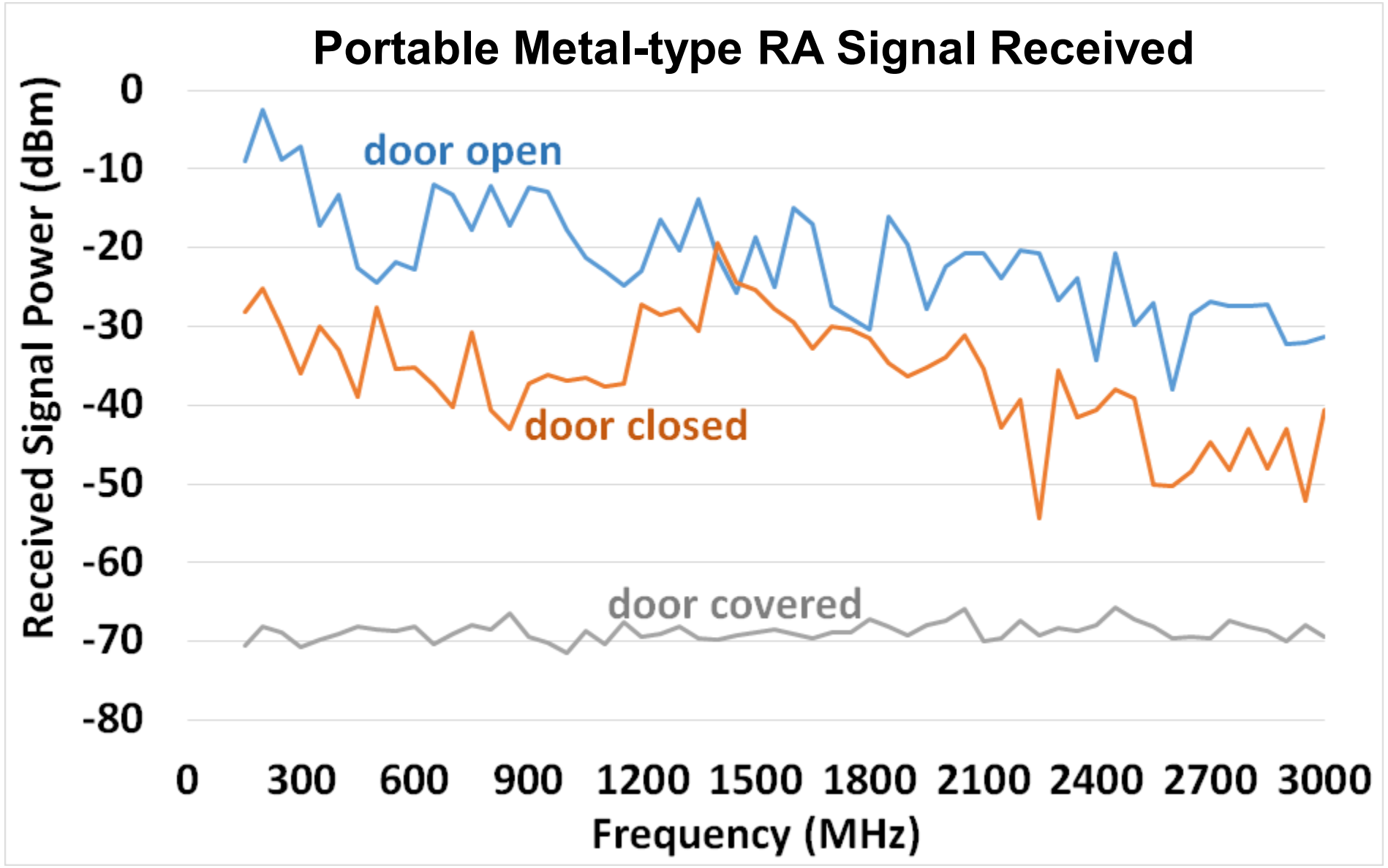
6-PERSON METAL RA



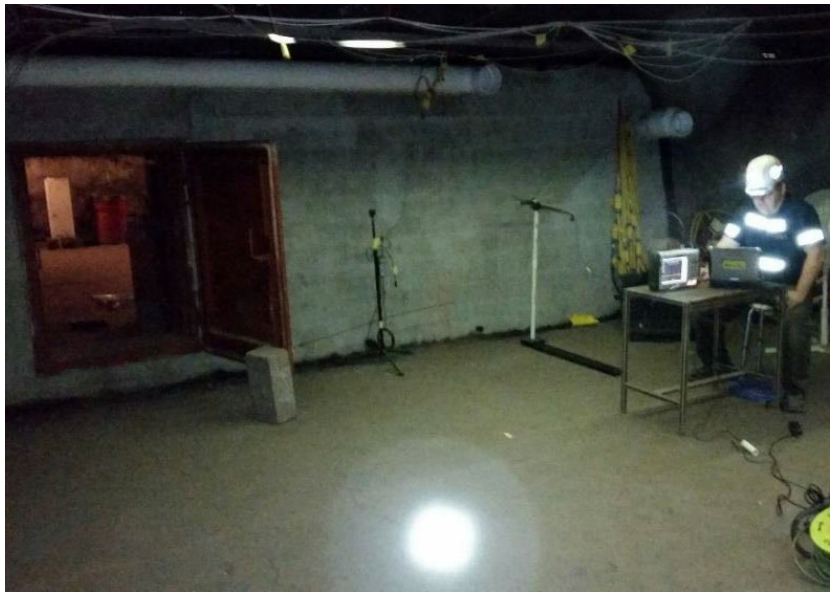
Results for a metal-type RA in the Experimental mine

- Results showed an average of 15 dBm attenuation when the door was closed and latched
- The door's seal may allow signal to enter the signal to enter the RA
- Researchers investigated placing a steel plate over the door to determine if this is the signal entry point
- Signal could not penetrate the RA when the door was completely covered by a steel plate

Results indicate that the door seal allows the signal to enter

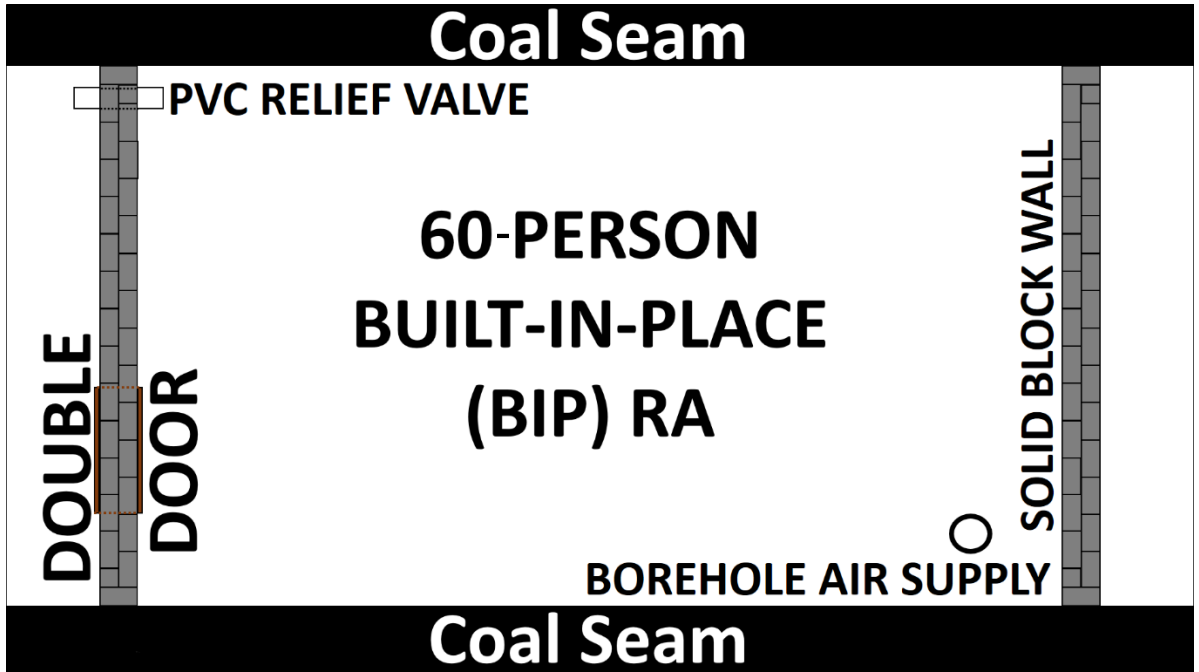


NIOSH performed signal attenuation measurements on a BIP RA



Built-in-place RA, 60-person

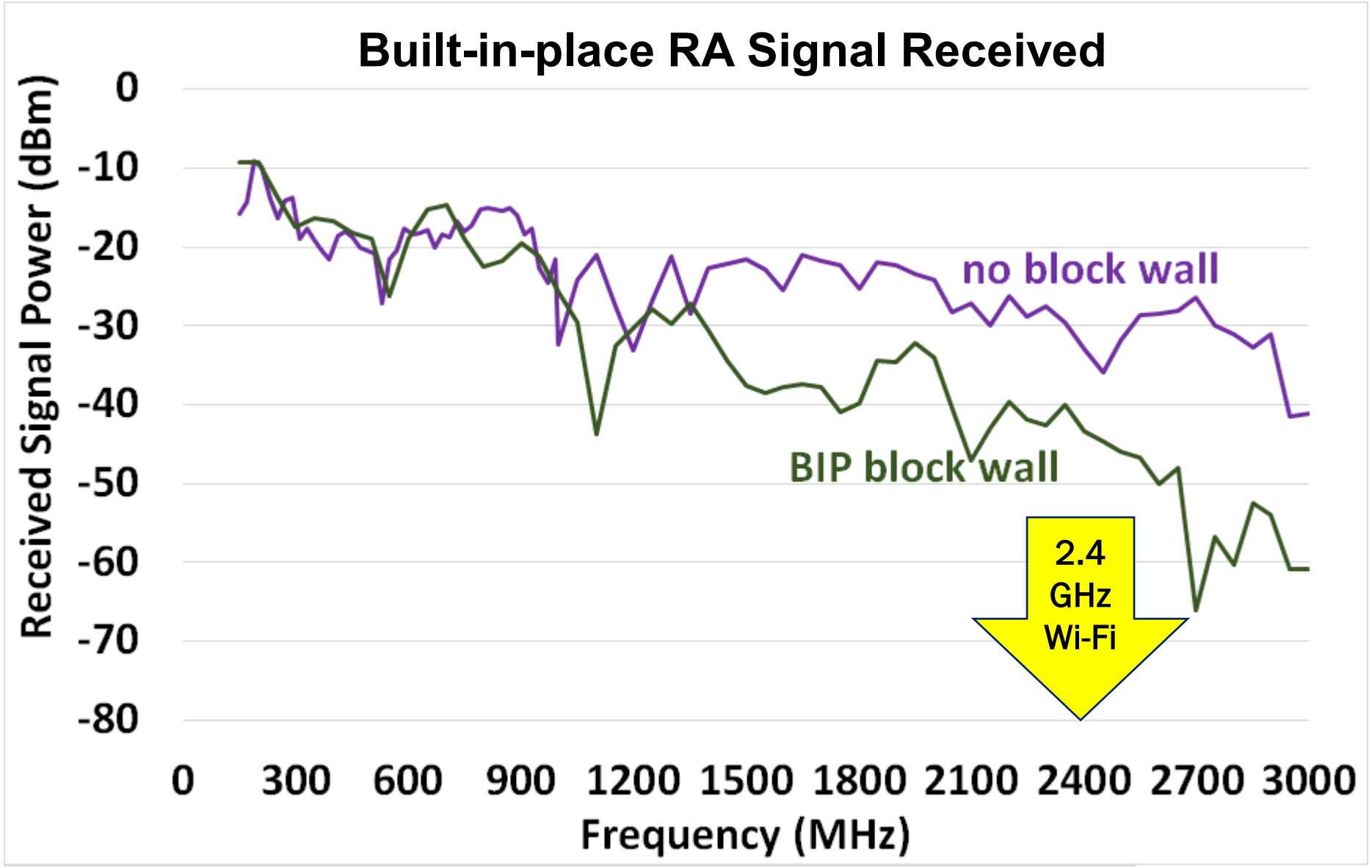
- Constructed of two layers of solid concrete blocks and a steel double door
- Each block weighs 23 kg, 40 cm long by 19 cm wide by 14 cm high
- 13 m long by 6 m wide by 2.1 m high



Results for a built-in-place RA in the Experimental Mine

- The BIP RA reduced the signal by an average of 14 dBm
- Higher frequency signals affected more than lower frequency signals

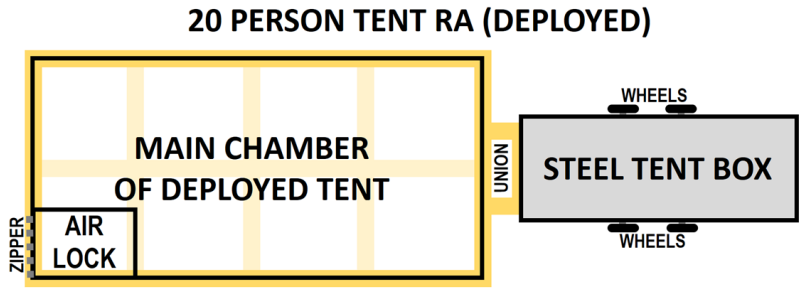
Results show the block wall attenuates the signal more at high frequencies



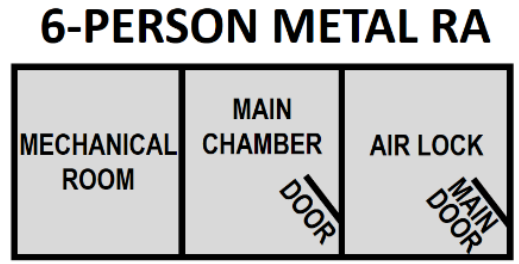
Summary for refuge alternative communications

- Signal attenuation is dependent on system frequency and RA type

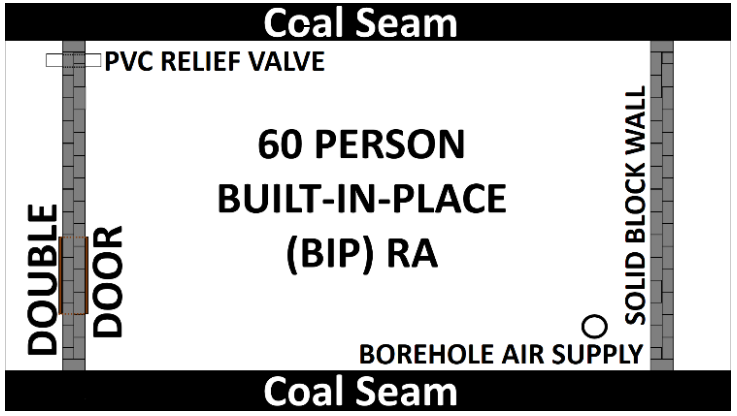
- As expected, the tent-type RA had little impact on signal
- The signal was on average 10 dBm higher than the other two RA types



- The metal RA reduced the signal 15 dBm on average
- The door seal was found to be the source of the signal entry into the RA and must be present to allow wireless signal into the RA



- The BIP RA reduced the signal by an average of 14 dBm
- Higher frequency signals affected more than lower



Questions?

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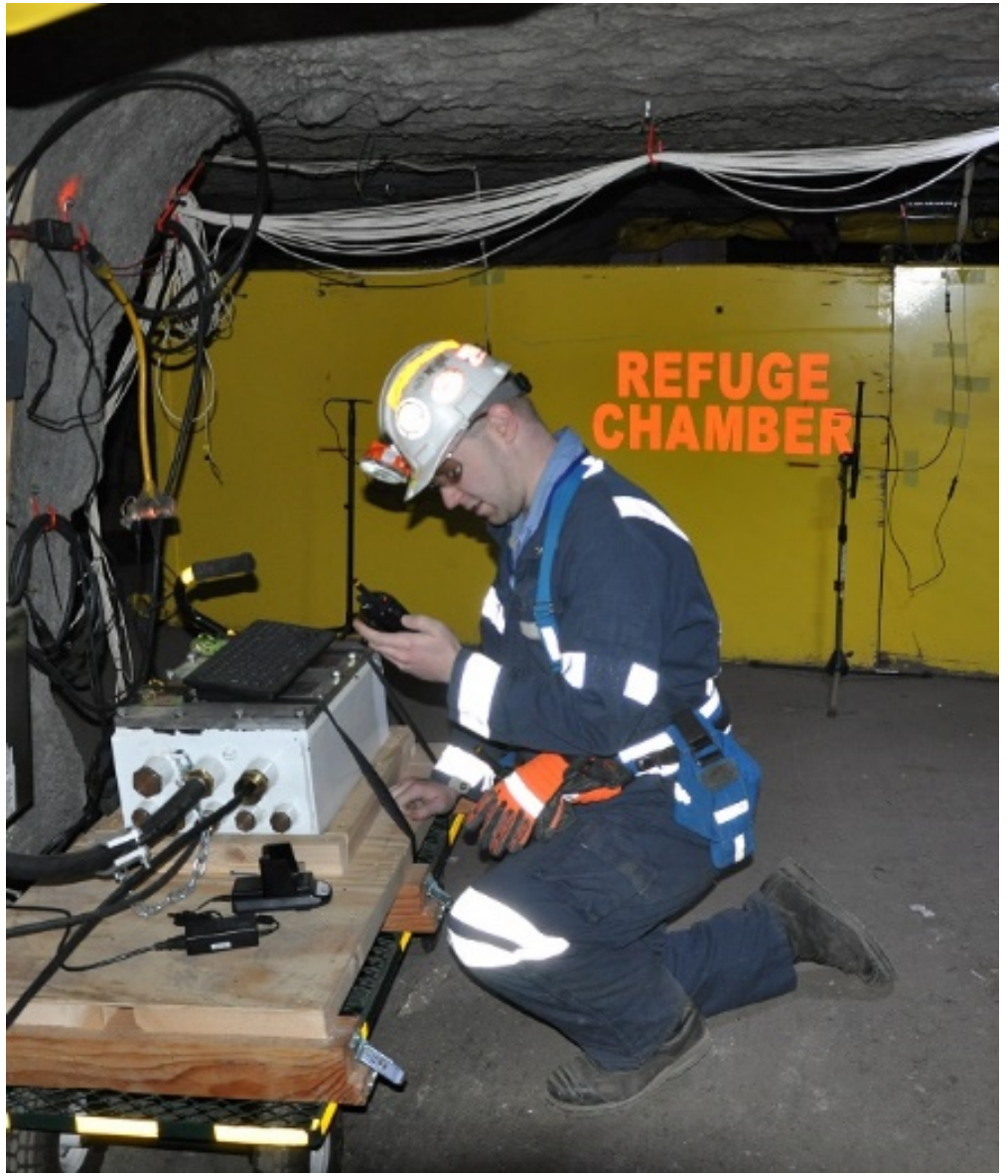

References:

Damiano NW, Zhou C, Whisner BG [2018]. Considerations for communications systems in underground refuge alternatives. In: Proceedings of the International Mechanical Engineering Congress and Exposition (IMECE), Pittsburgh, PA. ASME, IMECE2018-87952, Nov. 9-15.

Damiano NW, Homce GT, Jacksha R [2014]. A review of underground coal mine emergency communications and tracking system installations. Coal Age, 119(11):34-35.