

ITU/WMO Seminar “Use of Radio Spectrum for Meteorology: Weather, Water and Climate Monitoring and Prediction”

Session 6: Meteorological Radars

6.1.1 Weather Radars



Presented By:

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Earth Resource Technologies Inc.

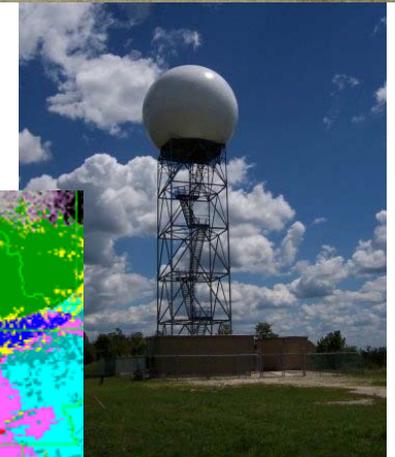
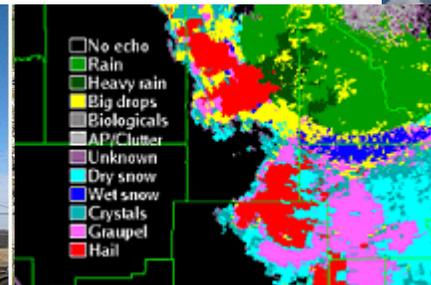
For : NOAA-National Weather Service

September 2009

Meteorological Radars

Agenda

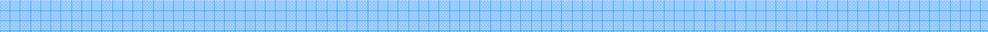
- **Weather Radars**
 - Frequency Bands
 - System Overview
 - Operations
 - Data Utilization
 - Impact of Interference
- **Relevant ITU Documents**
- **Looking Forward**
- **Conclusions**



Weather Radars

Frequency Bands

Weather Radar Frequency Bands



Frequency band (MHz)	Band Name
2 700-2 900	S-Band
5 250-5 725 <i>(Mainly 5 600-5 650 MHz)</i>	C-Band
9 300-9 500	X-Band

Weather Radars

Operations

Present and Future Frequency Band Needs

- **Band selection is a function of the trade offs between range reflectivity and cost which vary as a function of the physics of rain attenuation.**
 - **S-Band (2700-2900 MHz) is well suited for detecting heavy rain at very long ranges. (Up to 300 km)**
 - **C-Band (5600-5650 MHz) represents a good compromise between range and reflectivity and cost and can provided rain detection up to a range of 200 km**
 - **X-Band (9300-9500 MHz) weather radars are...**
 - **More sensitive than S or C Band Radars Used for short range weather observations up to a range of 50 km**

Weather Radars

System Overview

S-Band

- Operate in the 2700-2900 MHz Band
- In the US, WSR-88Ds operate up to 3000 MHz
- Typical peak transmitter power is ~750 kW
- 300 km Range
- Best Severe Weather Performance
- 159 operational S-Band NEXRAD Radars form the backbone of the US Severe Weather Warning System



Weather Radars

System Overview

C-Band (Commercial)

- Operates within the 5250-5725 MHz Band (Primarily between 5600-5650MHz)
- Typical transmitter power is ~270 kW
- ~200 km Range
- C-Band System are widely deployed on a worldwide basis
- Used by many TV Stations



Weather Radars

System Overview

C-Band (Government)

- **FAA operates 45 Terminal Doppler Weather Radar (TDWR's) systems at or near major airports in the US**
- **Operates within the 5500-5650 MHz Band**
- **Typical transmitter power is ~270 kW**
- **~90 km Range**
- **Detects hazardous weather conditions such as windshear, microbursts and gust fronts, tornadic winds and heavy precipitation (inferring thunderstorms at an airport)**



Weather Radars

System Overview

X-Band

- Operates within the 9300-9500 MHz Band
- Typical transmitter power is 100 W to 25 kW
- ~50 km Range
- Element of Center for Collaborative Adaptive Sensing of the Atmosphere (CASA) network
- Users of X-Band Weather Radars include:
 - TV stations
 - Military
 - Researchers
- Small physical size
- Low Cost compared to S or C Band Systems

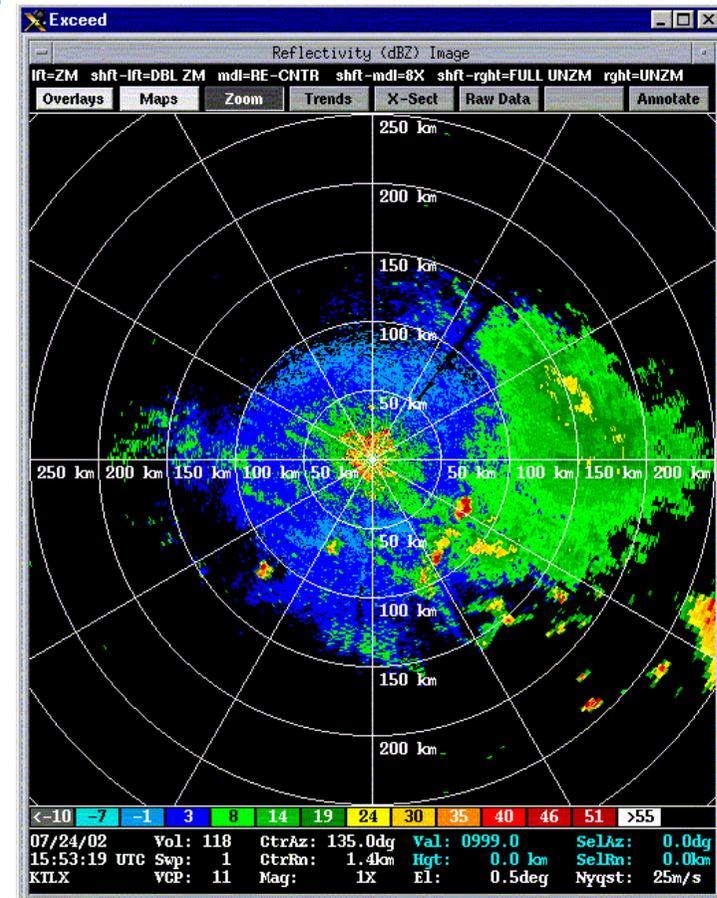


Weather Radars

Operations

Data Utilization – Base Products

- **Single Polarization**
 - Weather Forecasting Products
 - Base Reflectivity – Rainfall Rate
 - Mean Radial Velocity - Wind information that related to wind motions within and relative to a storm
Used for assessing rotation in a storm.
 - Spectrum Width – Detecting turbulence
- **Dual Polarization**
 - Differential Reflectivity - Indicator of drop shape.
 - Correlation coefficient – Indicator of regions where the is a mixture of precipitations types.
 - Specific Differential Phase – Also a good indicator of rain rate

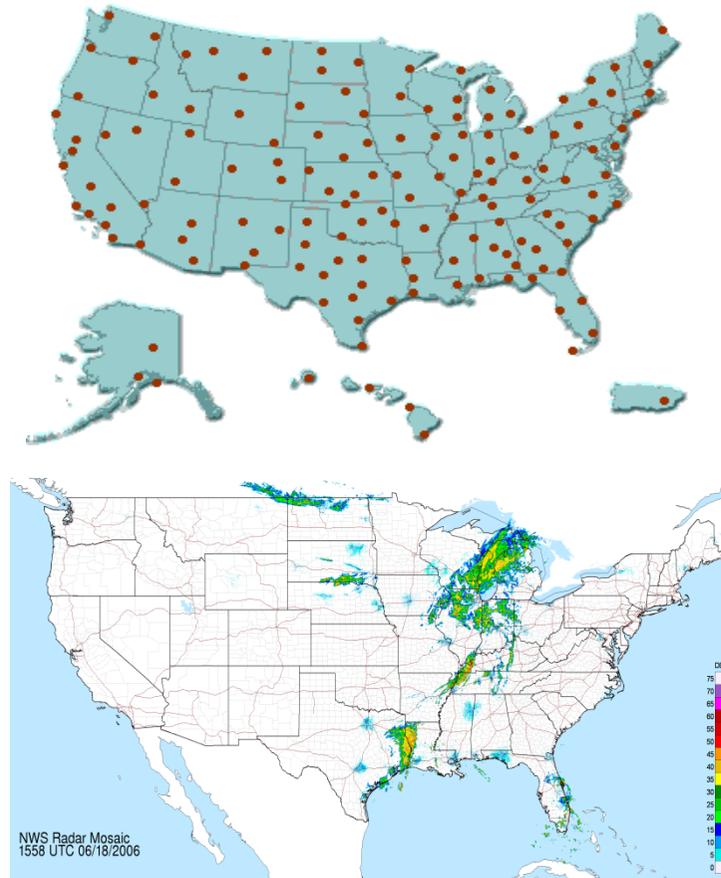


Weather Radars

Operations

US NEXRAD Network

- **Started Service in June 1992**
- **159 Network Sites selected to provide overlapping coverage**
- **Super Resolution Upgrade Began in June 2008 increased Doppler Data Range to 300 km from 230 km**
- **Provides Nationwide Reflectivity Mosaic**
- **Generates multiples levels of data which include....**
 - Level II data - meteorological base data quantities: reflectivity, mean radial velocity, and spectrum width.
 - 41 meteorological analysis products known as Level III data are generated from the Level II Data.
 - The data are sent to the National Climatic Data Center (NCDC) for archiving and dissemination.
 - A detailed description of these products can be found at <http://wf.ncdc.noaa.gov/oa/radar/radarproducts.html>
- **NEXRAD data is also used in hydrology, ecology, and environmental studies.**



Weather Radars

Operations

European Network (OPERA – Operational Program for the Exchange of weather RADar information)

- **150 Weather Radars**
- **Supported Within the OPERA Network**
- **Approximately 100 Doppler Radars**
- **Dual-Polarization is becoming the operational standard.**

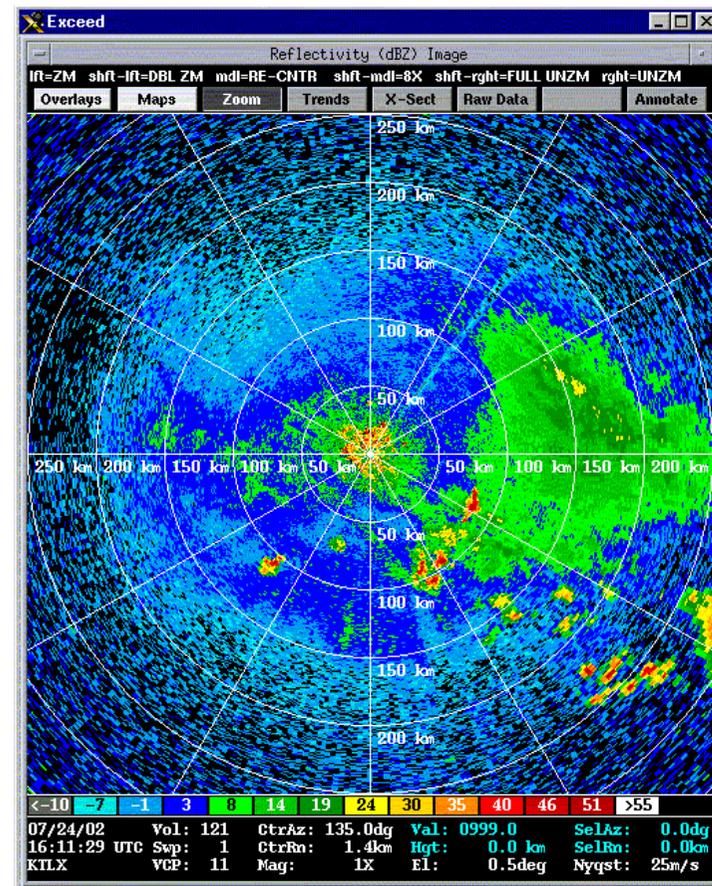


Weather Radars

Operations

Impact of Interference

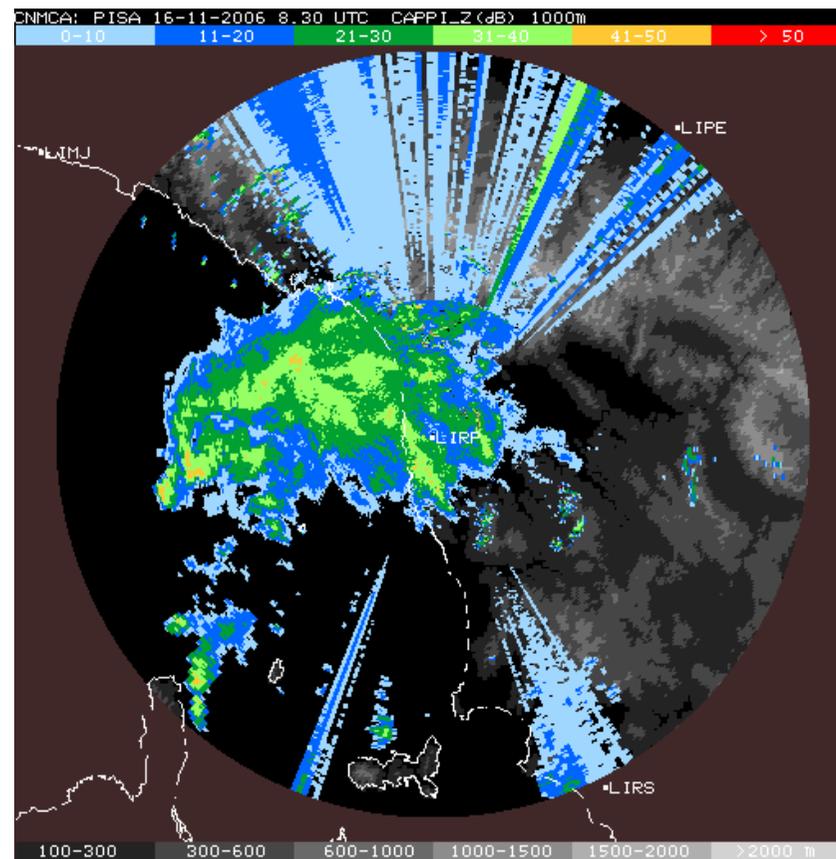
- **Corrupts Base Products**
- **Limits or nullifies the Radars Ability to....**
 - Detect wind speed and direction
 - Locate and track hurricanes, typhoons, tornados, gales
 - Provide reliable data to base severe storm or flash food warnings on.
- **Decrease Range**
- **Base Reflectivity – Distorts Rainfall Rate Estimates**
- **Types of Interference**
 - Constant
 - Time Varying
 - Pulsed
 - We continue to see interference despite trying to identify sources and mitigation strategies



Weather Radars

Operations

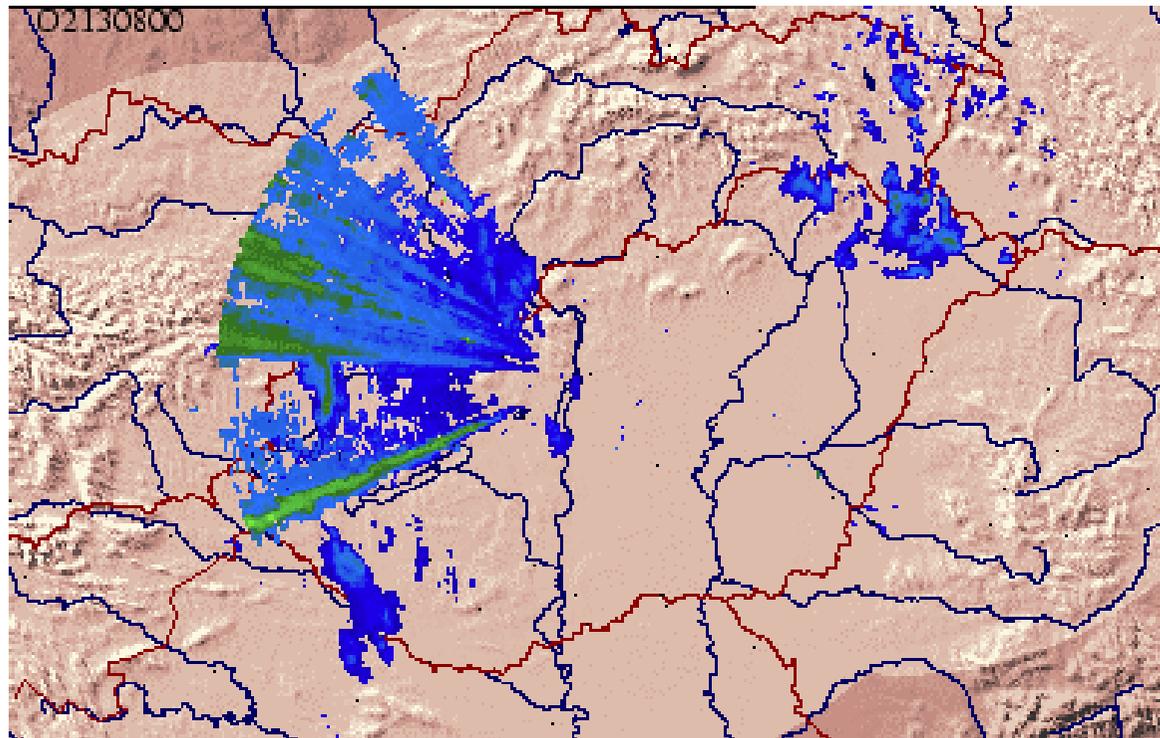
Impact of Interference – Types of Interference (Constant)



Weather Radars

Operations

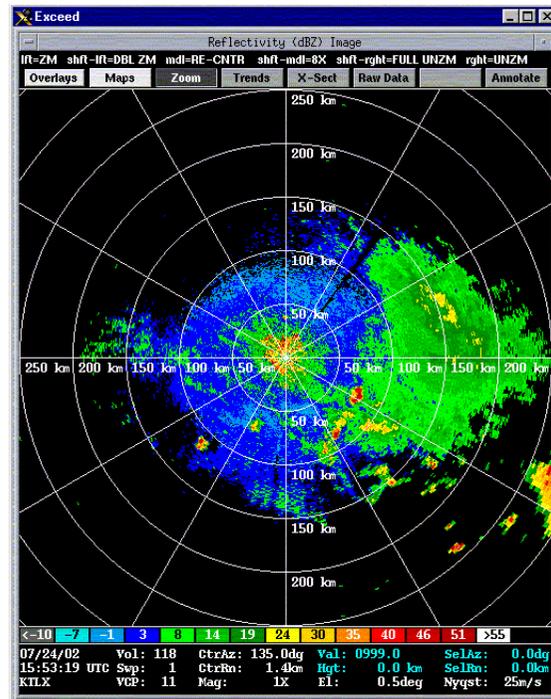
Impact of Interference – Types of Interference (Constant Interference from an RLAN)



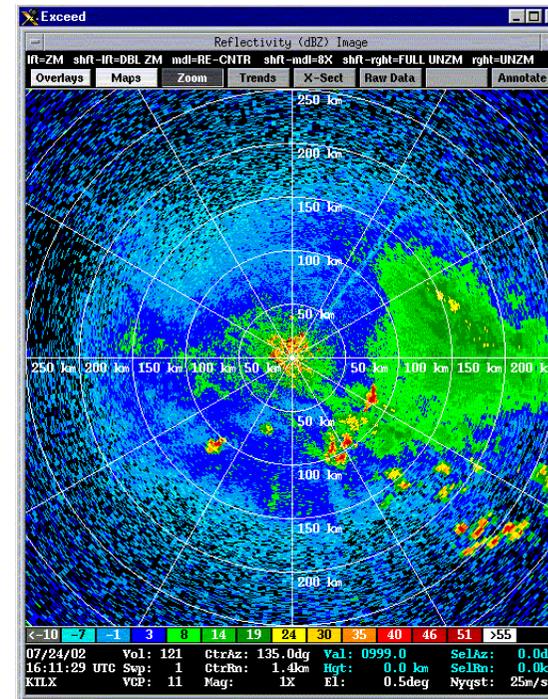
Weather Radars

Operations

Impact of Interference – Types of Interference (Pulsed)



Interference free



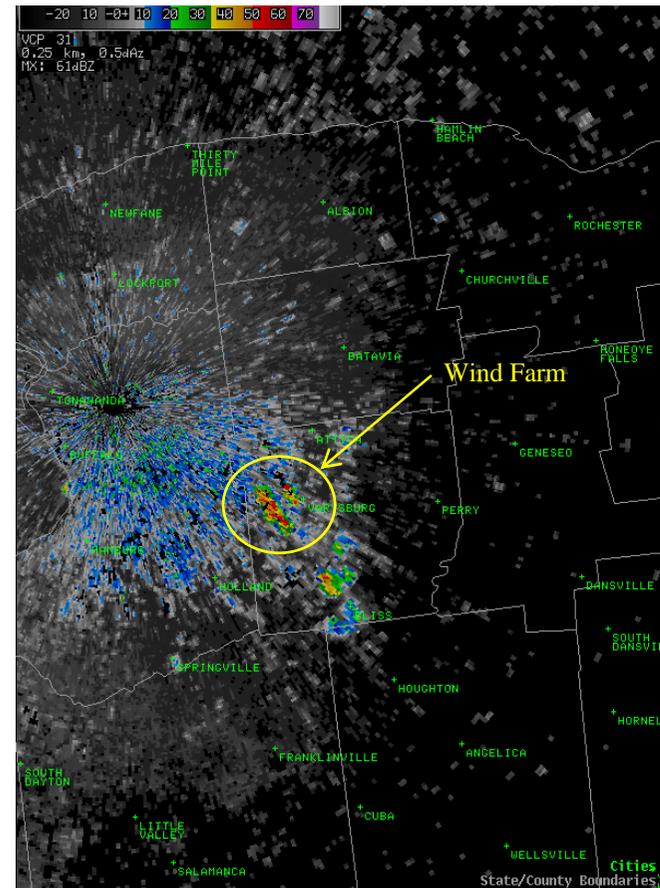
Interference corrupted

Weather Radars

Operations

Impact of Interference – Types of Interference (Wind Farms)

- **Thunderstorm characteristics could be masked or misinterpreted**
- **False reflectivity and radial velocity signatures could reduce forecaster's situational awareness during hazardous/severe weather events**
- **Data masking or contamination over the wind farm and down range from the wind farm may negatively impact warning effectiveness.**
- **False precipitation estimates could negatively impact flash-flood warning effectiveness**
- **Forecasters were able to 'work around' the impacts in this situation. Within ~18 km the impacts on data and operations begins to rapidly increase.**



Weather Radars

Operations

Impact of Interference On Our Lives

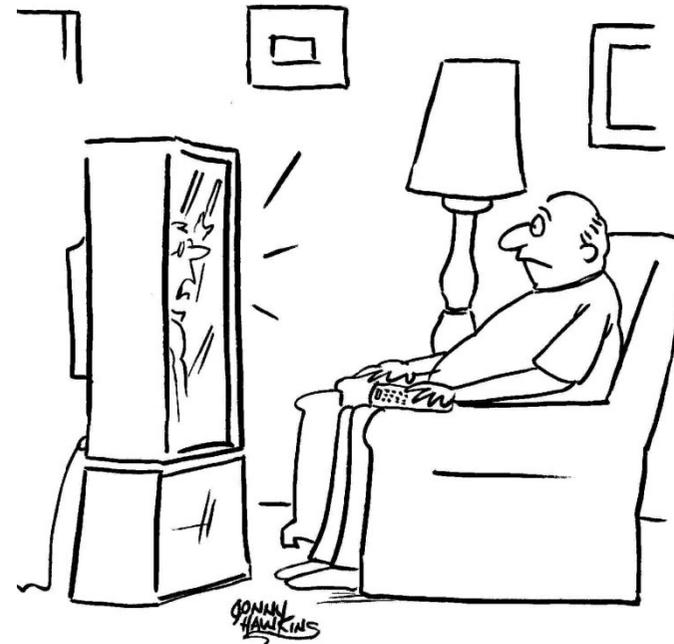
- **Routine weather forecasts**
- **Severe weather and flash flood warnings**
- **Aviation and maritime safety**
 - **Personal travel safety**
 - **Safe, timely transport of personal and commercial goods**
- **Agriculture – your source of food**
- **Power management**
- **Highway management**
- **Water management**

Weather Radars

Operations

Impact of Interference

At the end of the day, the bottom line is that interference dramatically reduces a Meteorologists ability to generate reliable forecasts.....



"Tonight's weather forecast is confusing, followed tomorrow morning by downright bewildering."

ITU

Definitions

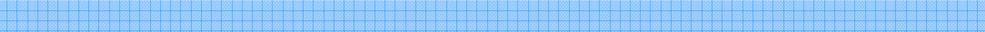
Weather Radars

- ***International Telecommunications Union (ITU)*** – U.N. organization responsible for international regulation of radio spectrum use
- ***International Radio Regulations*** – Treaty text maintained and enforced by the ITU that provides the regulations and table of frequency allocations for international radio spectrum use
- ***Radio Service*** - A type of radio operation, such as meteorological satellites, broadcasting, mobile-satellite
- ***Allocation*** – The authority for a radio service to use a particular frequency band
- ***License (or Assignment)*** – Authority for a particular radio station to use a specific frequency under the defined technical conditions and consistent with a frequency allocation

ITU

Definitions Applied To Meteorological Radars

Meteorological Aids Service (MetAids) – 400MHz and 1680 MHz Bands Radiosondes



- **In the ITU, Meteorological Radars fall under the Radiodetermination Service**
- **ITU Working Party 5B (WP 5B) is responsible for Meteorological Radars.**
- **Three allocations exist in the Radio Regulations specifically for meteorological radars**
 - **2700-2900 MHz- ground based radars**
 - **5600-5650 MHz- ground based radars**
 - **9300-9500 MHz- ground based and airborne radars**

Weather Radars

Relevant ITU Documents

Recommendation ITU-R M.1464-1

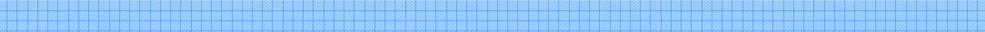


- **Content: Characteristics of meteorological radars and protection criteria for sharing studies**
- **Use: Used for performing analysis between systems operating in the radiodetermination service operating in the frequency band 2700-2900 MHz**

Weather Radars

Relevant ITU Documents

Recommendation ITU-R M.1849



- **Content:** Technical and operational aspects of ground-based meteorological radars
- **Use:** That the technical and operational aspects of meteorological radars as described in document be considered when conducting sharing studies and that the protection criteria for meteorological radars should be based upon Annex 1, in particular § 8.5, for assessing compatibility with interfering signal types from other services and applications.

Weather Radars

Relevant ITU Documents

Report TU-R M.2136

- **Content: Interference protection criteria analysis and testing results in the 2700-2900 MHz and 5600-5650 MHz Bands**
- **Use: Reference document**

Weather Radars

Relevant ITU Documents

Handbook R-HDB-45-2008-MSW-E

- **Content: Use of Radio Spectrum for Meteorology: Weather, Water and Climate Monitoring and Prediction**

- **Use:**

“The Handbook provides comprehensive technical and operational information on current observation applications and systems and on the use of radio frequencies by meteorological systems, including meteorological satellites, radiosondes, weather radars, wind profiler radars and spaceborne remote sensing. It is intended for the meteorological (i.e. weather, water and climate) and radiocommunication communities, including governmental institutions, industry as well as the general public.”

Looking Forward

Future System Trends

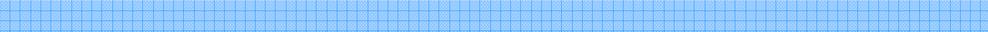
Weather Radars

- **Dual Polarization**
- **Phased array antennas**
 - **Allow other volume scan strategies**
 - **Can periodically return to an area of concern in atmosphere during a volume scan**
- **Increased automation**
 - **Mode selection**
 - **Severe weather signature detection**
- **The deployment of X-band gap filler radars where short range (mitigating cone of silence) or high resolution performance is needed.**

Looking Forward

Future ITU Activities

Weather Radars



- **Possible updates to ITU-R Documents**
- **New ITU-R Report on Determining Maximum Interference Levels for Dual-Polarization Radars Operating in the 2700-2900 MHz Band**

Conclusions

Weather Radars



- **Meteorological radars operate differently and produce different products than other radar types**
- **The differences need to be considered when conducting sharing studies**
- **Limitations of physics dictate frequency band use**
- **Meteorological radars with higher sensitivity – lead to greater interference sensitivity**

Conclusions

Weather Radars

- **Meteorological Radars are the backbone of day to day local, regional, national and global weather forecasting**
 - **Utilize segments of the Spectrum that are well suited to their operation**
 - **Provide data for local severe storm, aviation and marine forecasting**
 - **Save lives and injuries due to tornadoes –**
Simmons, K. M. and D. Sutter, 2005: WSR-88D Radar, Tornado Warnings and Tornado Casualties
 - **Sensitive systems that must be protected from interference**

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Weather Radars

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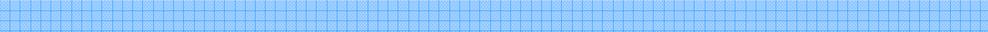
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Weather Radars



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Report ITU-R M.2136, Theoretical Analysis and Testing Results Pertaining to the Determination of Relevant Interference Protection Criteria of Ground-Based Meteorological radars, *ITU 2008*

Report ITU-R M.2112, Compatibility/Sharing of Airport Surveillance and Meteorological Radar with IMT Systems within the 2700-2900 MHz Band, *ITU 2007*

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Recommendation ITU-R M.1849, Technical and Operation Aspects of Ground Based Meteorological Radars, *ITU 2009*