Microwave RF Repeater Overview and Applications

Frank Martens
President - CEO

Ed Johnson
Vice President – Chief Engineer
Peninsula Engineering Solutions, Inc.
Peninsula Engineering Solutions

Who is PESi?
Who are we?
What do we do?
Peninsula Engineering Solutions
Corporate History

- Peninsula Engineering Group, Inc.
  - PEGI
  - 1983 – 1992
- Peninsula Wireless Communications, Inc.
  - PWC
- Repeater Technologies, Inc.
  - RTI
  - 1995 – 2002
- Peninsula Engineering Solutions, inc.
  - PESi, Separate independent company
  - 2001 – Current
We Love… Remote, Hostile Environments

- No Electric Power Lines
  - Low power consumption optimized microwave and cellular repeaters
    - *SmartPower™* developed for alternate power sources
      - Solar and Wind renewable power sources

- No Shelters
  - Avoid the high construction costs, air conditioning and heating expenses

- No Roads
  - Avoid the construction costs of access and maintenance roads

- Mountains, Deserts, Jungles… remote, hostile locations – we love them!
Services Offered

- MW Repeater Path Calculations
  - We can prepare path calculations.
  - or supply you with a path calculation tool.

- Configure the RF Repeater System and Site
  - Recommend antenna size and type.
    - Recommendations are integrated with terminal radios.
  - Supply the RF Repeater Equipment
  - Supply the MW Terminal Radio Equipment

- Remote Site Power Systems
  - Configure solar or wind sizing based on your goals.
  - Supply designed systems.
    - Remote Telecom Site Power Specialists
      - Microwave, Cellular, Wireless
Services Offered

- Installation Services
  - Install and test
    - Repeaters
    - Alarm system
    - Solar and wind power system
    - Antennas and cabling.

- Training
  - Systems and Applications
  - Products
  - Installation and Maintenance
  - Trouble shooting
Microwave RF Repeaters

Overview
Ed Johnson
Vice President – Chief Engineer
Microwave RF Repeaters

- RF repeaters relay microwave signals over obstructions like:
  - Mountains
  - Or buildings
  - Or use high point to reach distant towns

- Suited for fixed, point-to-point telephone, video, circuit switched data and IP packet data networks
Microwave RF Repeaters

- Designed for limited access, remote locations and harsh weather conditions.
- Economical solar electric battery power is ideal for operating repeaters.
RF-6000E MW RF Repeater

- 5925 ~ 7125 MHz
- 30 MHz Ch BW max
  - EW: 40 MHz BW
- 2 PA Levels
- Low DC Power
  - < 30 W
    - PA L1 DX Protected
  - < 40 W
    - PA L2 DX Protected
Why are RF Repeaters Needed?

- Microwave path can not directly reach the distant end.
  - Path is too long, earth curvature blocks path.
  - Terrain between radio ends is too high and blocks path.
  - New building blocks the path.
Why are RF Repeaters Needed?

- Tall antenna towers make project cost too much.
  - Long distance path clearance requires tall towers.
    - Earth bulge, K factor
    - High terrain obstruction
  - Mid-path RF repeater station costs less than tall towers.

Upgraded from 2 GHz to 6 GHz, Repeater and Feed Horn change
Why are RF Repeaters needed?

- Multipath fading makes long path unreliable.
  - Outage time is proportional to \((\text{path length, } D)^3\), two shorter segments are up to 4 times more reliable.
    - Direct = \(D^3\)
    - Mid Path Repeater
      \[= (D/2)^3 + (D/2)^3 = 2D^3/8 = D^3/4\]
      - Assumes equal fade margins
Benefits of RF Repeaters

- Simplify radio relay route planning.
  - Easy to engineer.
  - Site selection is easier than for back-to-back radios.
  - Site engineering and installation requires less work than for back-to-back radios.

- Improved system reliability.
  - Simple equipment is field proven, extremely reliable.
  - Radio paths using RF repeaters are very reliable.

- Improve multi-hop packet data networks.
  - Very low latency per RF repeater.
  - Very low jitter per RF repeater.
Benefits of RF Repeaters

- **Reduced site costs.**
  - Outdoor mounted equipment eliminates shelter requirements in most areas.
  - Low maintenance eliminates need for frequent road access.
  - Low power operation reduces mains power equipment needed.

- **Inexpensive to operate.**
  - Solar and wind power use “free energy”.
  - Few components, simple.
  - Easy to maintain.
When should RF Repeaters be used?

- When the Microwave Path is obstructed or too long.
- When the Radio Relay Station does not require circuit drops.
  - RF Repeaters are “Through Repeaters”.
- When the Radio Relay Station requires simple and reliable construction.
  - Difficult mountain terrain
  - No roads
  - No electric power lines
  - Rapid installation, quick in-service time
- When a remote, unattended station requires highly reliable equipment and low maintenance.
Relocation and Migration from 2 GHz, Considerations for RF Repeaters

- Existing path may use an RF repeater.
  - Higher frequency band models may be used.
- Higher frequency bands may have worse propagation.
- Narrower beamwidths are more prone to decoupling, beam wander.
  - Shorter hops work better.
    - 30 ~ 50 km, 20 ~ 30 mi in 4 to 8 GHz.
  - Longer hops can become two shorter hops through an RF repeater.
Relocation and Migration from 2 GHz, Considerations for RF Repeaters

- Higher frequency bands require solid reflector antennas rather than grids.
- Narrower Beamwidths require stiffer towers.
- RF repeater site may use larger antennas for isolation requirements and also reduce the need for larger antennas at the radio terminal sites.
  - Reduce radio terminal site tower upgrade or replacement costs.
  - RF repeater high sites typically use shorter towers.
Compatibility with radios

- MW RF Repeaters are generally compatible with most available microwave radios. Few limitations.

- Primary variables
  - Frequency Band
    - Point-to-point communications bands, USA, Int’l
  - Occupied bandwidth
    - Normal channel plans supported
  - Modulation
    - FM/FSK to 512QAM and COFDM
    - Easily adapts to new modulations
      - Channel Bandwidth and Linear Power Setting
Compatibility with radios, Modes and Functions supported

- Linear RF Repeaters are able to support a wide range of modes and functions found in modern radio equipment.
  - Automatic Transmit Power Control, ATPC
  - Adaptive Coding and Modulation, ACM
  - Dual Polarization, Co-Frequency, XPIC
  - Traffic modes: TDM, ATM, SONET, SDH, PDH, IP-Packet, Mixed TDM & IP-Packet/Ethernet
  - Video modes: Digital, Standard Definition, High Definition
Packet Data, Ethernet and IP Applications

- Linear RF Repeaters are compatible with advanced microwave radio equipment supporting packet data traffic. RF Repeater’s “transparency” continues to maintain compatibility as technology advances.
- Packet data is sensitive to network latency or propagation delay.
- RF Repeaters offer very low latency.
  - 100 ~ 150 nanoseconds typical per repeater
  - Equivalent to 0.150 microseconds or 0.00015 ms
Microwave RF Repeater Applications

How to best use MW RF Repeaters
Microwave RF Repeater Applications

- Mountain Top Radio Relay Station

- Microwave RF Repeater

- West Terminal

- East Terminal
Microwave RF Repeater Applications

- Tandem Microwave RF Repeater Stations

West Terminal

East Terminal
Microwave RF Repeater Applications

- “Y”-Junction RF Repeater Station

Through Traffic is looped
Microwave RF Repeater Applications

- "H"-Junction RF Repeater Station
  - Multi-Line Repeater routes traffic to multiple terminals.
Microwave RF Repeater Applications

- Combination Tandem “Y”-Junction Microwave RF Repeater Stations

Diagram showing connectivity between West Terminal, West Central Terminal, East Central Terminal, and East Terminal.
Microwave RF Repeater Applications

- Passive Reflector (short leg) and Tandem Microwave RF Repeater Stations

Diagram showing Passive Reflector and Tandem Microwave RF Repeater Stations.
A Repeater Site with a View!

- Citizens Communications – now Frontier
  - Near Ferndale, CA
    - Overlooking the Pacific Ocean at Cape Mendocino.
  - 6 GHz, migrated from 2 GHz in 2001
  - Solar Powered
  - Alcatel MDR-8706-16 terminal radios
Military Repeater

- RF-2000 Repeater at Nellis AFB near Las Vegas
- Solar Powered
- Tower Mounted
- 4-DS1 Capacity
- Migration candidate
Dam Link

- RF-2000 Repeater at Kortes Dam serving the power plant below
- USBR operated
- Solar Powered
- Mounted on HV Transmission tower
- Upgrade planned to 8 GHz, 1-DS3
Compact Repeater Passive Upgrade

- MWD of SoCal
- RF-6000E
- 135 Mb/s TDM, IP
- Upgrade passive repeater 2005
  - Fade Margin 37dB from ~3dB
- Low visibility
- Solar Powered
- Alcatel MDR-8606 terminal radios
Y-Junction Repeater

- Verizon California
- 11 GHz, NB Chan
- Migrated from 2 GHz CC in 2003~04
- 2x RF-11000-51
- Solar and Wind Powered
- 16-DS1 per route
  - 2 Carrier x 16-DS1 on common leg to CO
Verizon California

Y-Junction Repeater and 11 GHz Microwave System

COVINA, CA
WHS993
Lat: 34-05-09.0
Lon: 117-53-19.2
Gnd Elev: 570.99'/174.04m
Alcatel MDR 8711-16 Radio
2 TR

PIN E M TN, CA
WHS994
Lat: 34-13-24.0
Lon: 117-54-06.2
Gnd Elev: 4539.94'/1383.79m
Peninsula Engineering Solutions
RF-11000-51
RF Repeaters, 2 ea

CRISTAL LAKE, CA
WHS996
Lat: 34-18-41.0
Lon: 117-50-10.2
Gnd Elev: 5039.94'/1536.19m

EAST FORK, CA
WHS995
Lat: 34-14-17.0
Lon: 117-49-10.2
Gnd Elev: 1530.98'/466.65m
Alcatel MDR 8711-16 Radio
ENTEL Chile

- 34 Mb/s Capacity.
- Alcatel 4PSK radios.
- Terminal Penon 30 km to Repeater Mingre 37.5 km to Repeater Loma del Rio 2.8 km to Terminal Constitucion.
Arizona Telephone Co

- RF-11000, 11GHz
- 45 Mb/s
- Upgrade from passive – 2008
- Solar powered
- Aviat TRuepoint 5200 radios
- Grand Canyon NP
Repeater Selection

Product Summary
Repeater Selection Considerations

- Microwave Frequency Band
  - Products currently available 1.5 - 11 GHz.
  - Nine major repeaters in family operating in worldwide, point-to-point microwave bands.
  - Products serve
    - US Telephone Operations
    - US Operations Fixed
    - US Federal Agencies
    - International Operations
Repeater Selection Considerations

- Repeaters for US Telco and Ops Fixed

<table>
<thead>
<tr>
<th>Frequency Band</th>
<th>RF Repeater Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.7 ~ 2.3 GHz</td>
<td>RF-2000E</td>
</tr>
<tr>
<td>2.4500 ~ 2.4835 GHz</td>
<td>RF-2500E</td>
</tr>
<tr>
<td>2.4 GHz ISM DSSS Unlicensed</td>
<td>RF-2500E-01-SS</td>
</tr>
<tr>
<td>5.9 ~ 7.1 GHz</td>
<td>RF-6000E</td>
</tr>
<tr>
<td>10.7 ~ 11.7 GHz</td>
<td>RF-11000</td>
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Repeater Selection Considerations

- Repeaters for US Federal Agencies

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<th>Frequency Band</th>
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<tr>
<td>2.200 ~ 2.290 GHz</td>
<td>RF-2000E</td>
</tr>
<tr>
<td>2.4 GHz ISM DSSS Unlicensed</td>
<td>RF-2500E-01-SS</td>
</tr>
<tr>
<td>4.4 ~ 5.0 GHz</td>
<td>RF-4500</td>
</tr>
<tr>
<td>5.7 ~ 5.8 GHz U-NII Unlicensed</td>
<td>RF-6000E</td>
</tr>
<tr>
<td>7.1 ~ 7.9 GHz</td>
<td>RF-7000E</td>
</tr>
<tr>
<td>7.7 ~ 8.5 GHz</td>
<td>RF-8000E</td>
</tr>
</tbody>
</table>
## Repeater Selection Considerations

- **Repeaters for International Applications**

<table>
<thead>
<tr>
<th>Frequency Band</th>
<th>RF Repeater Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.39 ~ 1.54 GHz</td>
<td>RF-1500E</td>
</tr>
<tr>
<td>1.7 ~ 2.3 GHz</td>
<td>RF-2000E</td>
</tr>
<tr>
<td>2.3 ~ 2.7 GHz</td>
<td>RF-2500E</td>
</tr>
<tr>
<td>4.4 ~ 5.0 GHz</td>
<td>RF-4500</td>
</tr>
<tr>
<td>5.9 ~ 7.1 GHz</td>
<td>RF-6000E</td>
</tr>
<tr>
<td>6.4 ~ 7.1 GHz, 40 MHz BW</td>
<td>RF-6000EW</td>
</tr>
<tr>
<td>7.1 ~ 7.9 GHz</td>
<td>RF-7000E</td>
</tr>
<tr>
<td>7.7 ~ 8.5 GHz</td>
<td>RF-8000E</td>
</tr>
<tr>
<td>10.7 ~ 11.7 GHz</td>
<td>RF-11000</td>
</tr>
</tbody>
</table>
Repeater Selection Considerations

- **Route of Network at Radio Relay Station**
  - Through, Y-Junction, H-Junction or Custom Station.
  - Hundreds of configurations available.

- **Single or Tandem Repeaters**
  - Tandem practical limit is 3 to 4 repeaters.
  - Depends on traffic, modulation and hop distance.
    - Delay equalization is available and recommended.
    - Low Latency advantage over radio repeaters.
Repeater Selection Considerations

- Working Channels and Protection Configuration
  - 1+0, 1+1, 2+1, 3+1, ... 7+1.

- Frequency Plan
  - T/R Spacing
  - T-T Spacing
  - Channel Bandwidth

- Traffic Loading
  - 1.5 Mb/s ~ 2 Mb/s to 155 ~ 200 Mb/s Typically.
  - Dependant on terminal radio capacity.
Repeater Selection Considerations

- Modulation of Terminal Radios
  - FM, QPSK, QAM, TCM are typical modulations.
  - Typical RF Power operating levels, dBm.
Repeater Selection Guide

- Peninsula Engineering Solutions has prepared a Microwave RF Repeater Selection Guide “Guidelines for Selection and Link Design” to assist in making choices.
- Please consult the guide book when you are choosing Microwave RF Repeaters.
- Available on the PES web site.
  - www.peninsulaengineering.com
  - and on CD
Characteristics, Considerations and Configurations
Primary Characteristics of Microwave RF Repeaters

- **On-Frequency Repeater**
  - No Frequency Change, F1 in, F1 out!

![Diagram showing 1+1 Duplex Configuration]
Configurations Available

- 1+0, 1+1 Hot Standby Equivalent Duplex
- 1+0, 1+1 HSBE Space Diversity Duplex
- 1+1 Frequency Diversity Duplex
- 1+1 Hybrid Space and Frequency Diversity Duplex
- 1+0, 1+1 Y-Junction Duplex
- 1+0, 1+1 One-Way, Simplex
- 2+1, 3+0 Duplex
  - 2-working channels and 1-protection channel
- 3+1, 4+0 Duplex
  - 3-working channels and 1-protection channel
- 4+1 ~ 7+1 are combinations of these
Space Diversity Configurations

- **2-Frequency, 1+0/1+1 Hot Standby**
  - Long Path – Short Path

- **4-Frequency, 1+1 Frequency Diversity**
  - Any path length or radio type
  - Hybrid or Quad Diversity
    - Hybrid Space + Frequency Diversity
    - Product of individual improvements
Configurations Available

- **1+0/1+1 Hot Standby Duplex Space Diversity.**
  - Space diversity receive antennas on the long path.
  - V-H Polarization separated co-channel short path.
  - Diversity combining at the far terminal receiver.
  - Recommended for 34, 45 Mb/s or lower and 32 TCM, 16 QAM or simpler modulation with standard 30 dB XPD.
  - Higher XPD is required for 155 Mb/s, 64 QAM and above.
  - XPD ≥ Receiver T/I
Configurations Available

- 1+1 Duplex, Hybrid Space and Frequency Diversity.
  - Space diversity receive antennas on the long path.
  - Single antennas, frequency diversity on the short path.
  - Diversity combining at the far terminal.
  - Recommended for all capacities and modulations.
Space Diversity
MW RF Repeater Link

Notes:
(1) Short Path has very low probability of fading
(2) Short Path antennas can be Gabriel UCC_X, RFS UXA or Equivalent.
(3) Short Path XPD >35dB to control co-channel interference to acceptable amount.
   a) Normally determined by MW Radio Receiver Threshold to Interference, T/I rating.
2-Repeater Box, Y-Junction

F1, F1’

F3, F3’

H-Pol

V-Pol

Common
Dual Polarized
1-Repeater Box, Y-Junction

F1, F1’

F3, F3’

Common
F1, F1’
F3, F3’
Single Pol
RMAS Alarm System

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Alarm System for Microwave RF Repeaters

- **Remote Monitor and Alarm System**
  - Remote Monitoring or Supervision

- **RMAS-120**
  - Microcontroller based Alarm Transmitter and Receiver.
  - 1+0 to 3+1/4+0 configurations per unit.
    - 1 ~ 8 amplifier equipped repeaters.
    - 4+1 ~ 7+1 require 2ea RMAS-120 units.
  - Low Power consumption.
    - Ideal for solar powered installations.
Alarm System for Microwave RF Repeaters

- Supervisory alarm equipment provides ability to monitor remote RF Repeaters.
  - Alarms are sent to RMAS-120 Receiver Unit installed at nearby terminal microwave radio station.
  - Alarms are extended into the network via contact closures.
RMAS-120 Receiver
Alarm System for Microwave RF Repeaters

- Local LED indicators for visual alarm checks.
  - Receiver LED indicators show current alarm condition.
    - Sync Loss will flash on loss. Reset to clear.
  - Transmitter LED indicators may be normally disabled to conserve power.
  - Activated on button push.
    - Lamp Test first, then alarm condition
Alarm System for Microwave RF Repeaters

- Special design adds telemetry to microwave carrier without data stream or baseband access.
  - MW carrier amplitude modulated 1 dB P-P at 32 baud, matching fast fade rates.
  - Detected at terminal AGC voltage.
    - AGC eliminates telemetry from the terminal data demodulator.
- Compatible with most types of continuous carrier terminal radios.
  - Digital, Analog or Video
Alarm System for Microwave RF Repeaters

- Not all MW radios are compatible with the RMAS-120 AM Telemetry.
- UHF Radio link is an alternative transmission from the repeater to the terminal.
  - Parallel to the LOS MW path.
    - 60 mile, 100 km LOS link distance.
  - Low power continuous operation.
  - 900 MHz Unlicensed Band.
  - 2400 MHz Unlicensed Band.
  - Spread Spectrum, FHSS to manage interference
  - MW AM is eliminated.
    - Independent from the MW Radio characteristics.
RMAS with UHF Radio

- RMAS-120 Tx with 900 MHz UHF Tx and data combiner.
- 900 MHz UHF Rx unit and data output distributor.
Alarm System for Microwave RF Repeaters

- Uncommitted inputs for monitoring other station equipment.
  - Perimeter security.
  - Tower lights.
  - Power system.

- RMAS 120 Transmitter installed inside repeater enclosure
  - Weather protection.
  - Security.
Monitored Conditions

- **Amplifiers**
  - Current and RF power output.
  - Each amplifier is individually monitored.

- **Power Equipment**
  - Battery voltage
  - Battery temperature
  - AC charger
  - AC mains
Monitored Conditions

- **Feedline Pressure**
  - Waveguide or Air Coax low pressure sensor
  - Protects against wet feedlines.

- **Security**
  - Open door alarm.
  - Inputs for site perimeter alarm.
  - Inputs for solar panel, battery or antenna security wire loop.
RMAS with SNMP Adapter

- **PES SL10 SNMP Link®** extends alarm outputs via SNMP over IP networks.
- Compatible with HP Openview®, Spectrum® and other SNMP-based network management systems.
  - Easy MIB integration.
- Generate SNMP traps sent to NMS via TCP/IP.
- Control other equipment with optional relay outputs.
- Monitor temperature and humidity with optional sensors.
  - Set alarms warning of damaging conditions.
Power Supply Systems

Remote Power
Remote Site *SmartPower™*
**SmartPower™**

- Use as little power as practical
- Lower power designs
- Higher efficiencies
- Incorporate higher gain antennas
- Manage current as demand varies
- Careful choice of solar and wind components
- Long life designs
- Lower life cycle costs
Power Supply Systems

- Solar Electric Battery Power
  - Ideal for installations too far from AC mains.

- Wind Turbine Electric Generators and Battery
  - Site Dependant
    - Need adequate winds
Power Supply Systems

- Thermal Electric Generators, TEG and Battery
  - Ideal for remote installations where solar power alone is insufficient.

- Motor Generator (Genset)
  - Suitable for larger site loads.
  - More efficient if combined with battery charging.

- AC Mains Power, Charger and Battery
  - Lower cost power equipment.
Power Supply Systems

- Hybrid Power Combinations
  - Improve economics in larger remote installations.

- Battery Charging Power Systems
  - Solar and Wind Turbine
  - Solar and TEG
  - Solar and Diesel Motor Generator
Solar Electric Battery Power

- Available almost everywhere in the World.
  - Suitable throughout the World except Polar regions.
- No fuel supplies!
  - Renewable power from the Sun.
- Economical and reliable components.
  - No moving parts.
- Battery Reserve
  - 10 - 30 days.
- Very Low maintenance.
  - Battery test
  - Clean Solar Panels
- Easy to install!
Solar Electric Battery Power

- Battery Reserve
  - 7 to 10 days to 30 days of battery autonomy recommended for most solar powered systems.
  - Low Arctic locations use 60 to 90 days autonomy.

- Redundant System Design, A + B
  - Two independent solar electric array and battery systems.
  - Each powers half the repeater load in normal conditions.
  - Should one system fail, the remaining system can power the entire repeater load with half the reserve time.
Wind Turbine Electric Generator

- Wind turns the turbine generating electricity from the spinning electro-magnetic field generator.
- DC output charges the battery.
- Best used in combination with Solar.
- Economical and reliable components.
- Battery reserve of 7 to 10 days.
- Low maintenance.
  - Check for damage to turbine blades
  - Controller and Regulator Test
  - Charging Test
  - Battery Test
- Straight forward installation
Thermal Electric Generators (TEG) and Battery

- Heat from burning fuel creates electricity in thermocouples and charges the storage battery.
- Uses Propane or Natural Gas for fuel
  - Recommend 12 to 15 months of fuel supply storage.
- Economical and reliable components.
- Battery Reserve of 3 to 10 days.
- Low maintenance.
  - Maintain adequate fuel.
  - Clean the burner jets
    - Sand can clog the small hole.
  - Battery Test
- Easy to install.
Motor Generator (MG) Genset

- Motor turns an electric generator.
- Motor fueled by:
  - Propane
  - Diesel
  - Natural Gas
- Higher power solutions
- Can be used in hybrid power systems
  - Solar, Battery
- Requires periodic maintenance
- Higher operating and lifetime costs
AC Mains Power Charger and Battery (BUPS)

- Suitable when AC Mains are nearby.
- No fuel supplies to maintain.
  - Grid electricity is distributed by wire.
- Very Economical power equipment.
- Battery Reserve of 8 to 48 hours.
- Low maintenance.
  - Battery test
  - Charger test
  - Check AC Mains wires
- Easy to install!
Peninsula Advantage for Site Power Systems

- Years of Experience.
- Knowledgeable on Telecom and Wireless requirements.
- Complete drawing package.
- Pre-assembled systems.
- All required assembly hardware and wire.
- Reduces on-site labor costs.
- Reduces installation time and mistakes.
- Training, installation supervision and commissioning are available.
Peninsula Advantage for Site Power Systems

- Standard Photovoltaic Arrays
- Standard Wind Turbines
- Standard Batteries
- “Engineered” Power Packages Available
  - UL Listed Components
  - Computer Aided System Design
  - Complete systems with all required components and installation instructions
Questions and Discussion

Thank You!
Contact Information

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