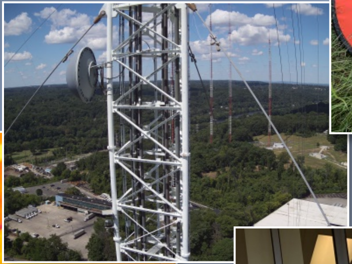
Using Drones as Diagnostic Tools for Broadcast Systems



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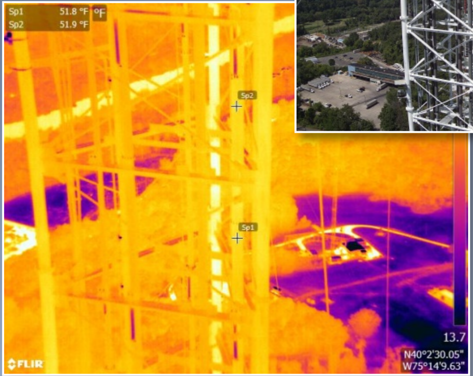

Engineering and Technology Consultants
Communications, Broadcasting, Media, System Technology & FCC Regulation

Using Drones as Diagnostic Tools for Broadcast Systems

Today we'll touch on:

- FAA aspects of using drone systems,
- Mission planning considerations,
- Drone based antenna measurements, and
- Drone (and ground) based thermography

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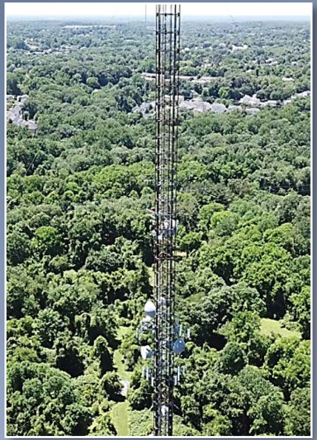
Uses for Drones

- Tower visual inspection
- Tower mapping
- Signal measurement
- Antenna pattern verification
- IR scan of RF components



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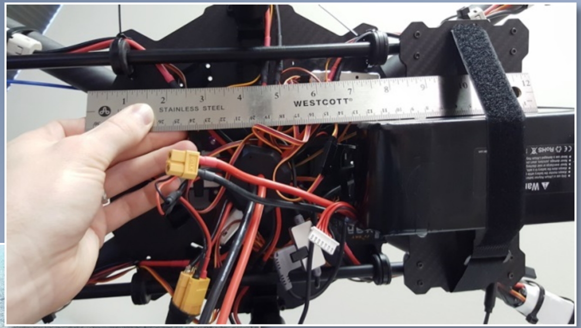
Drones - what you need to know

There is development time and cost involved

- What do you want it to do?
- Building your own vs Purchasing
- Battery life and length of flights
- Battery management/safety
- Payload capability
- Specialized Equipment



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Our Fleet

Each can be used for more than one purpose

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But first - what you need to know

The following is an informal snapshot of some of the FAA requirements for drone operation. Be aware that the FAA's rules frequently change! Check the latest FAA regulations and advisory circulars for changes.

"Drone" is the common term for what the FAA refers to as an "sUAS", or *Small Unmanned Aircraft System*

What is considered to be an UAS (sUAS)?

- ANY unmanned aircraft between 0.55 and less than 55 pounds

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Drones – FAA Rule Part 107

Most civilian drone operations fall under 14 CFR Part 107

Does the pilot need an FAA license?

Commercial Drone Operators need a "Remote Pilot Certificate" *to legally fly*. It requires the pilot to pass a written test. The certificate must be carried with you whenever you are flying a drone.

Recreational Drone Operators operate under a special "carveout" in the FAA rules. (see AC 91-57B)

Recreational pilots must pass simpler "The Recreational UAS Safety Test" ("TRUST"), and carry the proof of test passage with them when flying.

Drones – Recreational Pilots

- Cannot fly “for compensation” or <u>any</u> commercial reason
- Financial compensation, or the lack of it, is not what determines if the flight is recreational or commercial.
- Goodwill or other non-monetary value can also be considered indirect compensation by the FAA.
- *So doing a flight for the station “as a favor” might be an FAA Rules violation.*
- Recreational flight is simply flying for fun or personal enjoyment.

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Drones – Commercial Pilots

Commercial Drone Operators

- Can operate an sUAS on a commercial basis, for hire, for a governmental agency, or for a public safety agency.
- *Must take and pass a test for a Remote Pilot Certificate*
- *Must take recurrent training every 24 months*
- Have the ability to file FAA operational rule waivers

Drones must be FAA registered

For commercial operations, drones less than 55 pounds must be registered.

> *(Drones weighing 55 pounds or more require either an FAA Rule exemption via 49 U.S.C. 4480, or apply for and receive a Special Airworthiness Certificate.)*

For recreational flyers, drones *over* 0.55 pounds must be registered.

The drone should be clearly marked with the registration number on the outside of the aircraft.

Keep the registration active.
(It is valid for 3 years and is renewable.)

Carry proof of registration when flying.

Small UAS Certificate of Registration

Name: Cavell, Mertz & Associates, Inc.

Manufacturer: Aeronavics

Model: RFX45

Serial Number: ANRTF-120

Certificate Number: FA3AEC

Issued: 11/08/2017 Expires: 11

Small UAS Certificate of Registration

Registered Owner: Cavell, Mertz & Associates, Inc.

UAS Manufacturer: DJI

UAS Model: M300

Serial Number: 1ZNBJ7P00C00DB

Registration Number: FA3C3FHAWN

Issued: 05/03/2022 Expires: 05/03/2025

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Drones – watch for FAA rule changes!

Example: The FAA will soon require a "transponder" for drones.

This "Remote ID" rule will be effective starting September 16, 2023

After that date, all commercial drones must broadcast:

- An ID
- Location & Altitude
- Velocity
- Takeoff location and elevation
- Time hack

There will be 3 ways to meet the Remote ID rule:

- Use Remote ID capability built into the drone
- Use Remote ID capability from an add-on device
- Use an "FAA-Recognized Identification Area (FRIA)"

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Flight Planning - Practicality

Consider the purpose and the urgency of your mission in light of FAA, safety, and operational challenges. *A drone based approach may not always be suitable or practical.* For instance:

- *Sometimes the site RF levels are too high* at the site or at an immediately adjacent site.
  - Not all drones are “RF hardened” – internal circuits can be impacted.
  - RF overload can affect some payload devices, such as receivers or spectrum analyzers. You’ll need to think about whether filters and attenuators will be needed.
- *Sometimes the frequencies in use at a site can conflict* with a drone system’s telemetry link, control links, or sensors.
  - Some of the frequencies used in drone operations include 900 MHz, 2.4 – 2.4835 GHz, and 5.725 – 5.85 GHz.
  - GPS devices are often used for timing and positioning assistance. GPS frequencies include 1573.42 MHz, 1227.6 MHz and 1176.45 MHz

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Flight Planning - Safety

…a drone based approach may not always be suitable or practical.

- Map out where you need to fly with respect to buildings, guy wires, areas where people may be in harm's way.
- Use Google Earth™ to help figure out:
  - flight paths,
  - landing and takeoff zones,
  - emergency descent plans,
  - potential hazards.
- Compare that against an actual "boots on the ground" survey.

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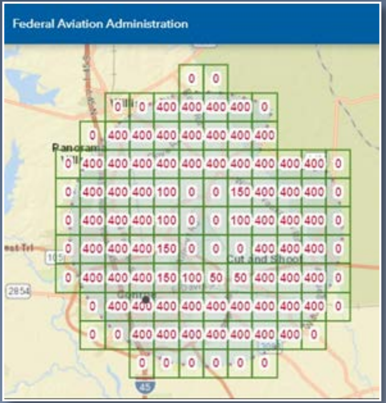
Flight Planning - FAA Considerations



- Pilots planning to fly *in controlled airspace around airports* must receive an airspace authorization from the FAA before they fly. Sometimes there are altitude limitations involved.
- Use the FAA's B4UFLY App, ALOFT, or similar app to check possible airspace issues, such as the proximity of your planned flight to airports.
- If the flight is near an airport in controlled airspace, request FAA LAANC* authorization (or an operational waiver, if necessary). The FAA has several LAANC providers.
- Depending on the airspace, near real-time authorization requests can often be coordinated quickly with the FAA.
- If the flight needs to occur *above* a LAANC designated permissible drone operating ceiling, a "further coordination request" should be filed.

**Low Altitude Authorization and Notification Capability*

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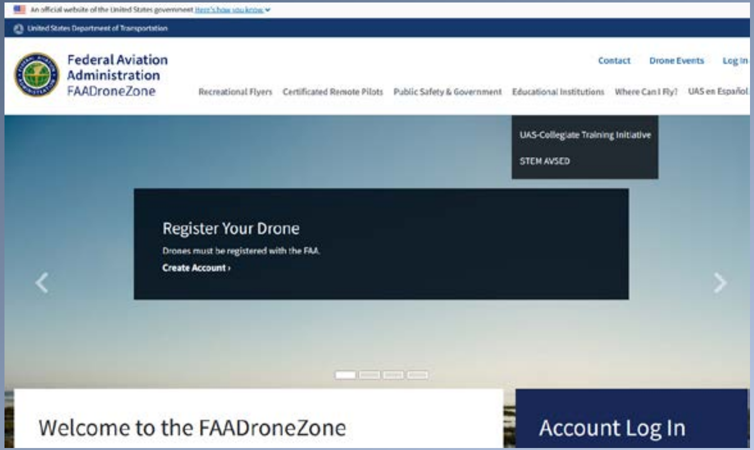
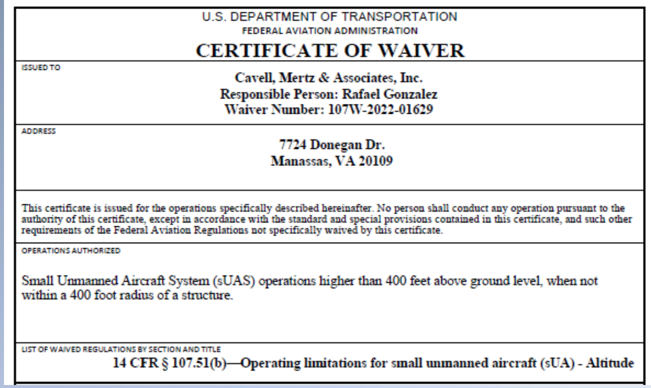
Flight Planning - FAA Considerations

When do you need to request an FAA Waiver?

- Operation from a moving vehicle
- Operating BVLOS
  (Beyond Visual Line of Sight)
- Operation over people
- Operation in certain airspace
- Operation *over* moving vehicles
- Operation in controlled airspace that requires a waiver and an airspace authorization

You must apply for a waiver through the FAA's "DroneZone" page





U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
CERTIFICATE OF WAIVER

ISSUED TO

Cavell, Mertz & Associates, Inc.
Responsible Person: Rafael Gonzalez
Waiver Number: 107W-2022-01629

ADDRESS

7724 Donegan Dr.
Manassas, VA 20109

This certificate is issued for the operations specifically described hereinafter. No person shall conduct any operation pursuant to the authority of this certificate, except in accordance with the standard and special provisions contained in this certificate, and such other requirements of the Federal Aviation Regulations not specifically waived by this certificate.

OPERATIONS AUTHORIZED

Small Unmanned Aircraft System (sUAS) operations higher than 400 feet above ground level, when not within a 400 foot radius of a structure.

LIST OF WAIVED REGULATIONS BY SECTION AND TITLE

14 CFR § 107.51(b)—Operating limitations for small unmanned aircraft (sUA) - Altitude

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Drones – Airspace Conflicts

You may not be able to fly at certain locations, such as

- Military Operations Areas (MOAs),
- Restricted areas,
- Prohibited areas (like Camp David),
- Flight Restricted Zones (FRZs),
- Special Restricted Flight Area (SFRA), or
- Areas under TFRs (Temporary Flight Restrictions).

The FAA and industry have various Apps and on-line tools that can help you determine if you may have an issue, such as B4UFLY, LAANC, and others. Always check "NOTAMS"

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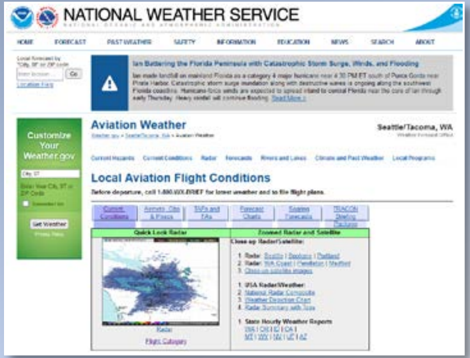
Flight Planning - Weather



Flying Requires suitable weather conditions

- Use “aviationweather.gov”, “weather.gov/sew/Aviation_Weather”, or the “UAV Forecast” app (or an equivalent) to get the weather *and* the wind profile for your flight.
- FAA Rule: Flight visibility must be no less than 3 statute miles
- FAA Rule: The minimum distance from clouds is 500 feet below, and 2000 feet horizontally from the cloud.
- Know the wind speed controllability rating of your drone.
  Know the wind speeds at all altitudes involving your flight.
- Flying when it’s raining is not wise

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Flight Planning – Operational Area

Where do you need to fly?

- For antenna pattern assessments, determine the radius needed for pattern azimuth measurements;
- Identify a distant point for elevation measurements
- Will you have to fly over people/roads/buildings?
- Do you need to work around other towers?

- For visual or IR inspections, what is a safe path up and required distance from the tower (mechanical obstruction clearance/RF saturation concerns).
- Will you have good GPS signals, and especially in the Landing Zone (“LZ”)? Check *GPS NOTAMS*
- Can you control public access from the operational area?
- Ensure ample space in the Take Off/LZ/emergency approach area.

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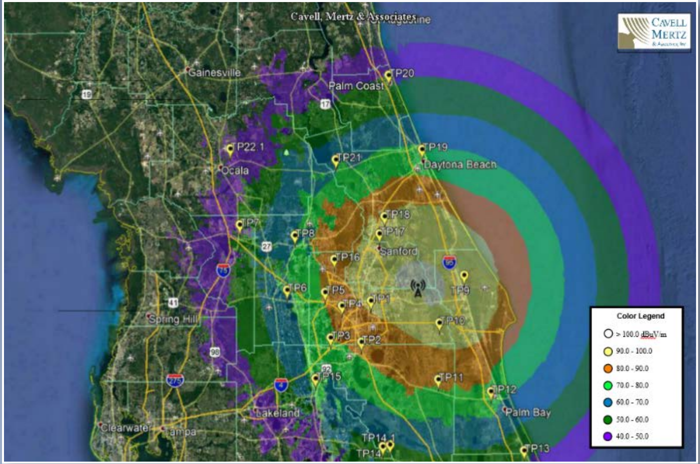
Specifics regarding TV/FM Antenna Measurements

Why would you want to undertake this?

- Someone suspects that coverage has changed
- Setting a benchmark prior to an antenna change, then verifying that it has been met after replacement
- Following suspected or known damage to the antenna
- Changes very near (tens of meters or less) in the antenna aperture
- Confirming that a new antenna system is working properly
- In some countries, periodic verification is required



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A Perspective on TV/FM Antennas

From our experience, almost all new antenna systems perform as designed, as confirmed by drone pattern studies.

For new antennas, those with issues generally seem to have been the result of shipping damage, on-site handling errors, assembly errors, or installation errors.

For TV, pretty much all post-construction issues reportedly involve directional antennas.

A report from a leading manufacturer said that their review of post-construction drone studies (of TV antenna systems) shows that pattern issues were found in about 13% of construction projects, most of which involved directional antennas rotated in the wrong direction, and "usually off by one bolt hole".

Most TV and FM antennas are very rugged and last for years. Issues with older antennas seem to be the result of weather induced damage (lightning strikes), lack of maintenance, inexperienced tower climber errors or carelessness, or vandalism (bullet holes).

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Pattern Verification Methods

Traditional Method

- <u>Measurement by ground based vehicle</u> - with antenna on a 30 foot mast
  - FCC accepted and easily compared against old benchmarks
- Alternative was ground based with shorter antenna elevation (~6 ft)
  - not as happily accepted; by the FCC height correction factor needed

- Equipment was a calibrated receiver and a chart recorder
  - Computers have replaced chart recorders
  - Spectrum analyzers are often preferred over traditional FIMs
  - Use of Software Defined Radio (SDR) systems is becoming possible

- The hassle factor is huge, even with a pneumatic mast system

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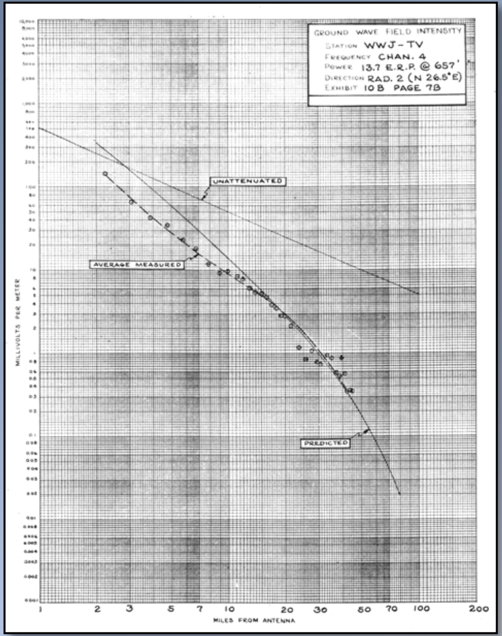
Pattern Verification Methods

Traditional Method

- The measurement data from the chart recorder or computer are plotted, spatially averaged, and compared against reference curves *for each radial measured from the site*
- From these graphs, distances to contours can be plotted on a map, or field strength estimates can be plotted on a polar graph. Conformance with the theoretically estimated field curve was felt to demonstrate proper signal radiation.
- Accuracy issues abound (due to localized effects, terrain shadowing, reflections…) but this was the best we had for decades
- The time required to collect, tabulate, and analyze the data is significant. Weeks are typically required, mostly due to the time required in the field. Elevation pattern was inferred from data.

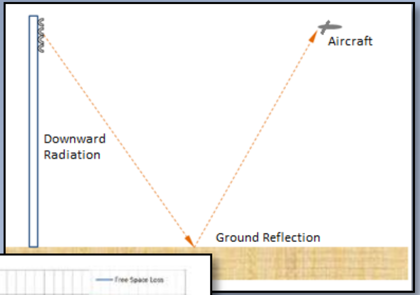


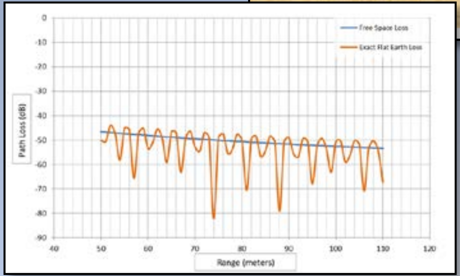
Pattern Verification Methods

More Recent Methods

Measurement by manned aircraft or helicopter

- Over the past few decades, conventional aircraft (airplanes and helicopters) have been used as an alternative to labor intensive, time consuming, ground based measurements.
- Not as readily accepted by the FCC and others
- Very costly to undertake - Costs include aircraft mods, rental, fuel, pilot
- FAA regulations can limit extent of height and flight path
- Elevation pattern measurements are often not feasible
- Orbits around the subject antenna are traditionally used, however the distances involved make the measurements subject to ground reflections, the effects of which can be severe and difficult to remove from the data.





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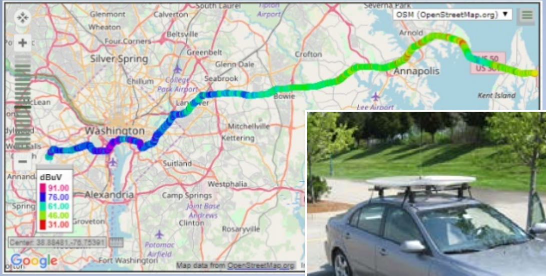
Pattern Verification Methods

More Recent Methods

<u>“Drive Tests” with vehicle mounted rooftop antenna system</u>

- Generally accepted by many broadcasters – not the FCC.
- Less costly to undertake than helicopter/plane method.
- True radial paths and “orbits” generally not possible.
- Technical issues include vehicle distortion of the receiving antenna pattern (mounting location sensitivity).
- Intervening local obstructions, and even passing trucks can corrupt the data.
- Generally good for “Before”/”After” comparisons
- Almost always limited to V-Pol orientation (magnetic mount vertical whip antennas are more commonly used).



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Pattern Verification Methods

Drone Based Measurements

- Have been used in recent years for:
  - Antenna Pattern Verification,
  - Coverage Field Strength Studies,
  - Propagation Model ‘Tuning’, and
  - Manufacturer Testing / R&D.

- Acceptance by the FCC for formal “Proof-of-Performance” purposes has not yet been attempted. However, ITU measurement Recommendations do exist.


Report ITU-R SM.2056-1
(06/2014)

report_E_2009

Airborne verification of antenna patterns of broadcasting stations

Experience exists worldwide for using drone based measurement systems for evaluating FM, TV, land mobile, microwave, radar, and HF systems.

The current accepted use in the industry in the U.S. is in pattern performance verification. The FCC Fund Administrator has reimbursed many stations for the cost of drone measurement services in the Television Band “Repack”.

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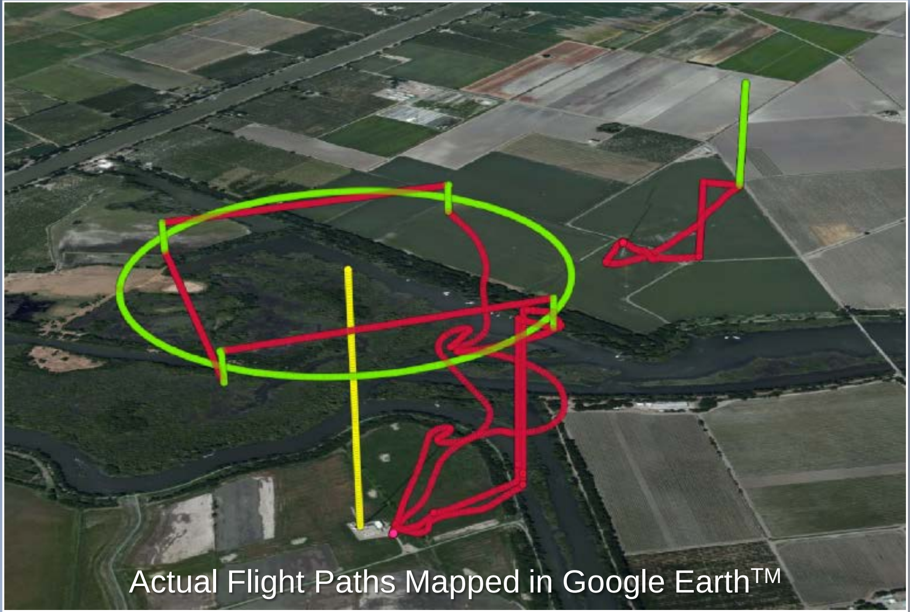
Pattern Verification Methods

Drone Based Measurements

- Can show horizontal plane pattern and elevation pattern in both polarizations.
- Will show if an antenna is not plumb.
- Can confirm beam tilt and pattern nulls
- Can help with pattern troubleshooting.
- Less expensive that other methods
- *They can fly relatively close to the tower*
    - This makes the calculation of ground reflection effects more predictable, because the downward radiation close in to the antenna is less, and the steeper ground reflection angle minimizes the issue.



Actual Flight Paths Mapped in Google Earth™

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Antenna Pattern Verification

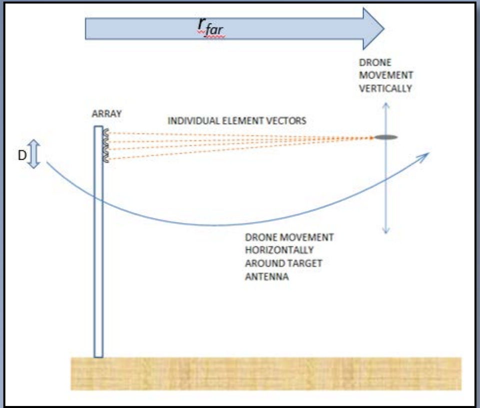
However, it is possible to fly too close

Accuracy can be impacted by flying too close to an antenna, such as flying in the reactive field. Flying in the far field is preferred because the pattern is fully formed there. The far field location can be determined by calculation using the Fraunhofer formula:

$$r_{far} = \frac{2D^2}{\lambda}$$

*So for example, for a 6-bay FM array, the far field is **24 m**;*

*For a UHF TV antenna with gain of 27 (2° beam), the far field is **>300 m**.*



However, from years of experience and collaboration with others, we are finding that flying in the more distal region of the near field can provide useful results when far field flight is impractical.

In particular, we have found that azimuth patterns can often be flown closer than first thought, with good results.

Additionally, as many of you are aware, some of our measurement work was used to support Dielectric's computer modeling effort. One of the results of this collaboration confirmed that near field *elevation pattern* flights can also successfully undertaken.[1]

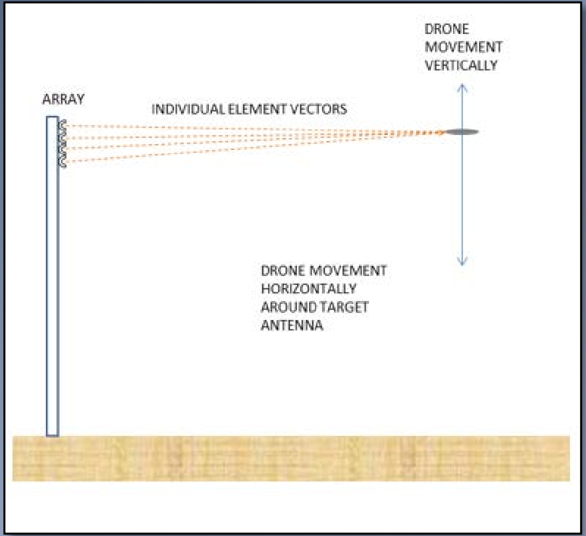
[1] - We understand that Dielectric can now support drone studies by modelling the antenna to confirm that the near field drone measurement results match based on simulated near field results. (If the data derived in their simulation and the field measurements match up, it can be concluded that the gain and far field data are as expected.)

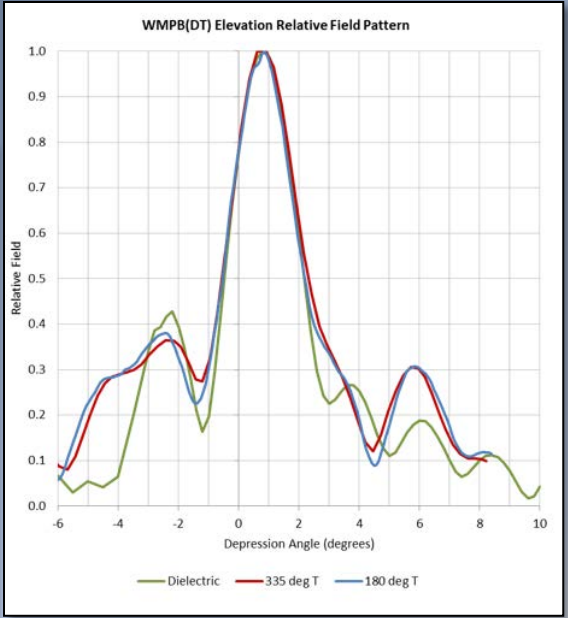
Antenna Pattern Verification

Elevation Pattern Measurement

Measuring the elevation pattern requires a careful ascent or descent to map where the beam center is, and the locations of the lobes and minima.

Beam tilt can be determined as can the possibility of mechanical tilt, whether it be purposeful (by design) or accidental, as in out of plumb antennas or towers. We select several equidistant points around the antenna to assess pattern maxima position.





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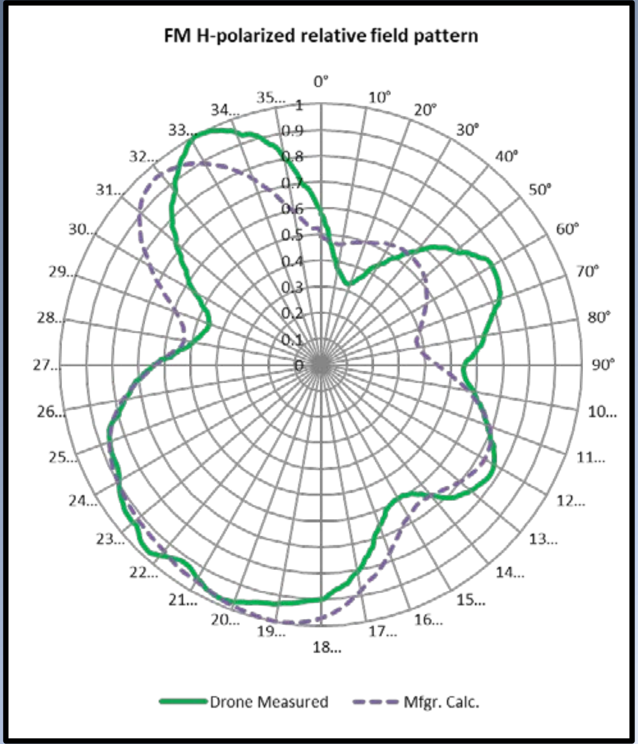
Antenna Pattern Verification

Elevation Pattern Measurement Examples

Using a drone system, “as-Installed” performance can be compared against the manufacturer’s baseline performance documents.

Regulatory compliance can be verified, as well as confirming that the pattern is directed toward the population of interest.



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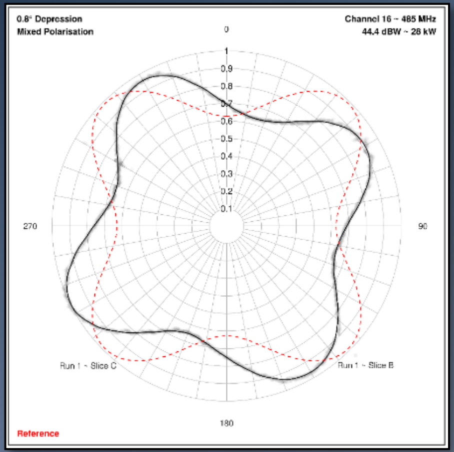
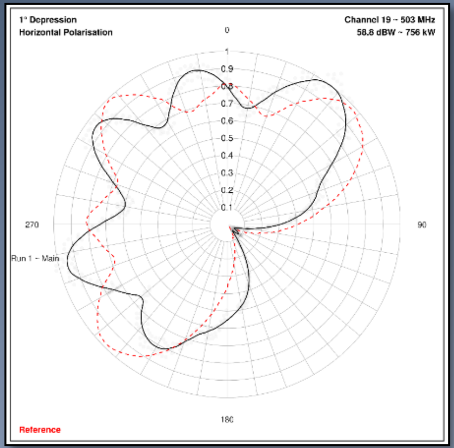
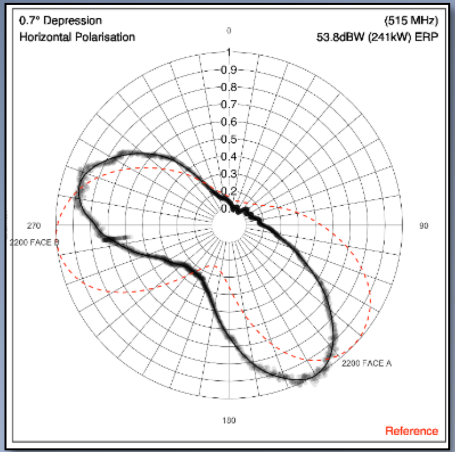
Antenna Pattern Verification

Examples of Installation Rotation Errors





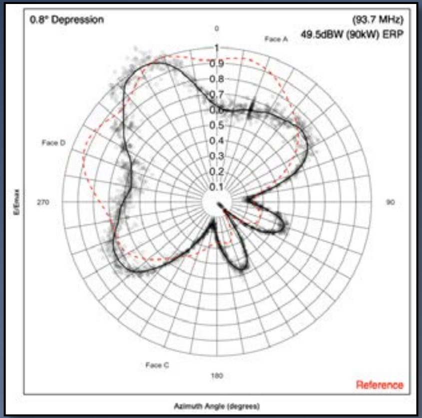


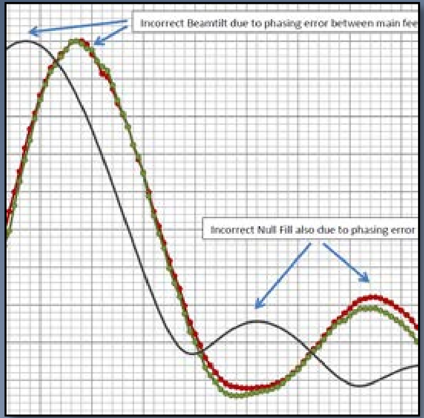
Typical problems include antenna rotation (alignment) problems, cable harness phasing errors, panel mounting errors, cable connector problems, or installing an antenna element (or even the whole antenna) upside down. - It's worth watching the installation crew carefully.

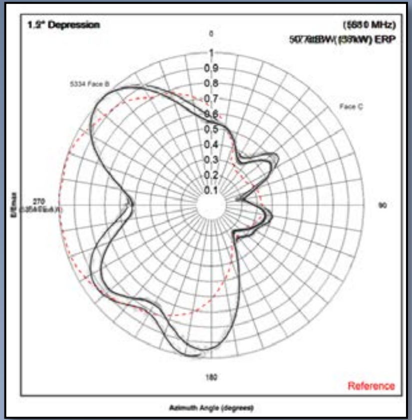
Studies courtesy of SixArms

Antenna Pattern Verification

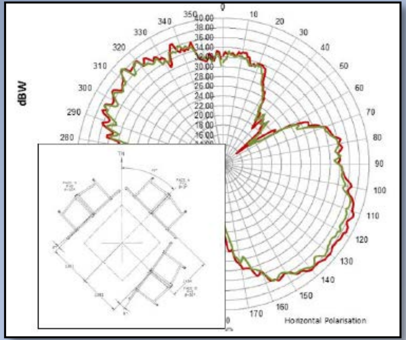
Examples of Installation Electrical Phasing Errors







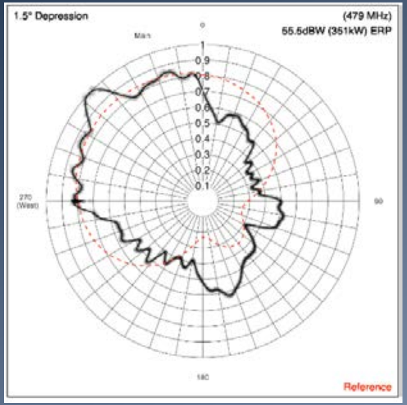
Inverted Panel

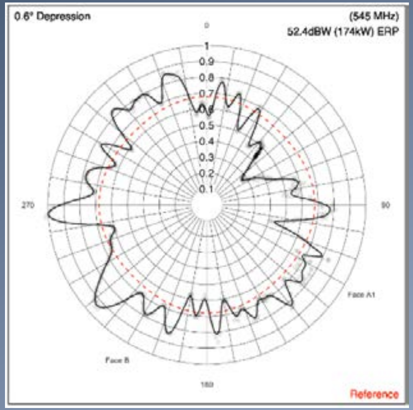


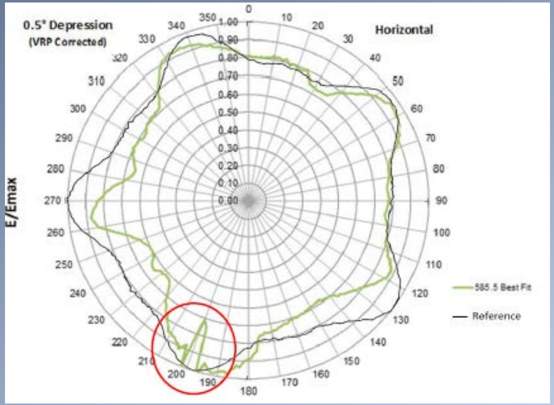
Studies courtesy of SixArms

Antenna Pattern Verification

Examples of Structural Effects





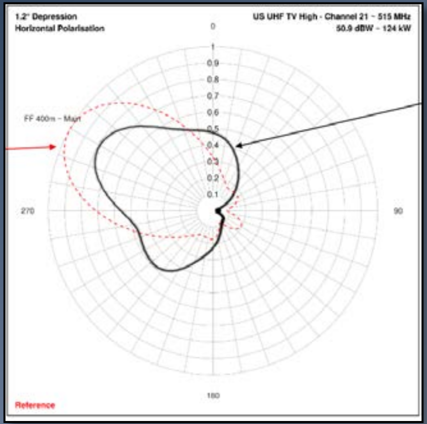


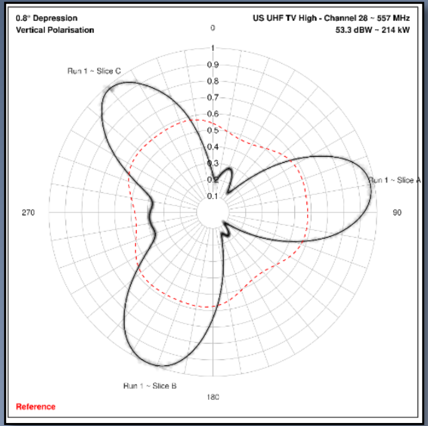
Generally seen on side-mounted antennas. A manufacturer's pre-install pattern study that accounts for the support structure, including everything metallic that passes through or near the antenna aperture can prevent most of these issues.

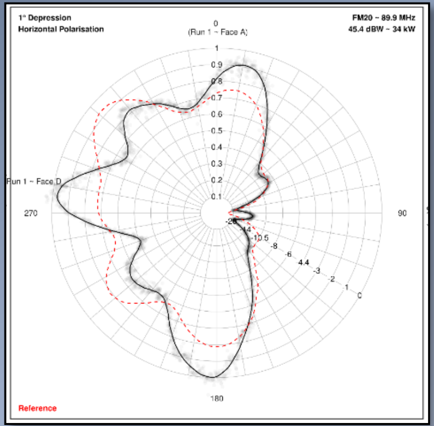
Studies courtesy of SixArms

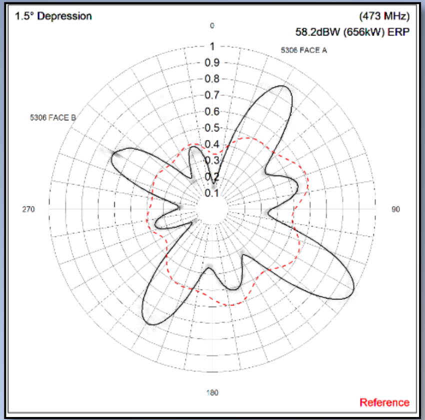
Antenna Pattern Verification

Examples of Apparent Design/Manufacture Problems









Studies courtesy of SixArms

Other Antenna/RF System Health Assessment Techniques

Often when an antenna or transmission line system is suspected of having issues (often hinted at by changing VSWR or lowering transmitter power indications), the preferred “go to” tool is a Vector Network Analyzer (VNA).

This device has the ability to identify faults in transmission lines and antennas, and can typically locate them with reasonable precision.

Unfortunately, decent VNAs can be very expensive to purchase, require a bit of experience to successfully operate, and require the station (and often nearby stations) to be off the air while in use.

Other disadvantages include their inability to reliably “see” beyond an initial fault (faults further down the line can be masked), and they may not see a problem that occurs when the system is in full power operation (“under load”).

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Other Antenna/RF System Health Assessment Techniques

Thermal (IR/Infrared) Imaging

One of the better tools for safely evaluating a system in operation can be an infrared (thermal) camera.

IR cameras detect the thermal energy being emitted by a device in the infrared part of the spectrum.

They can be used from a safe distance from the device being examined.

Prices for IR Cameras of reasonable quality have come down drastically in recent years, mostly due to the declassification of the technology and advances in on-board data processing.

The weight of the system and the optics has also decreased, making it possible for an IR camera to be deployed as part of the payload on a drone.

This makes possible a thorough examination of an operating antenna and transmission line system

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Other Antenna/RF System Health Assessment Techniques

Thermal (IR/Infrared) Imaging

The available devices range from the electrician's infrared thermometer, to a cell phone attachment, to handheld (and larger) systems.

Prices range from a few tens of dollars to over $250K, depending upon the device. Suppliers include Teledyne Flir and Fluke, among others.

Device quality/cost is dictated by the project need. The more expensive units can be rented from suppliers like Flir.

Flir offers webinars, how-to videos, and on-line and in person training classes and certification programs.

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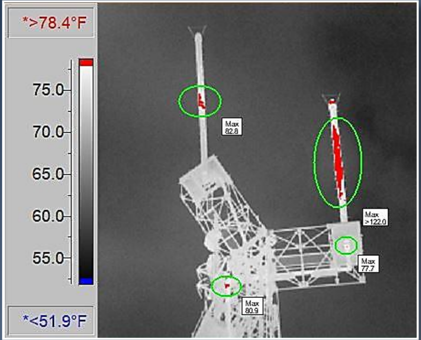
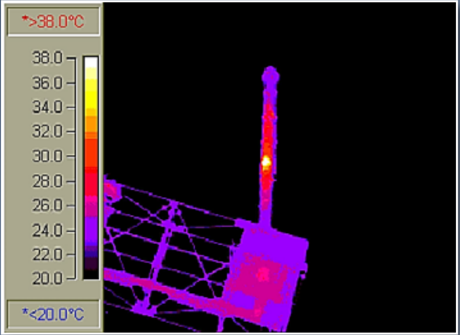
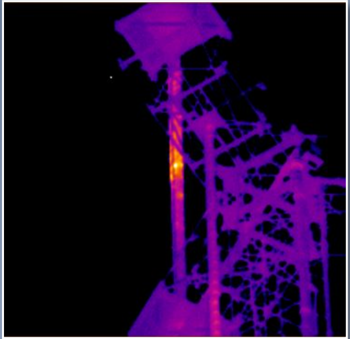
IR Scans – Case Examples

Here are examples of TV antennas in trouble







Elevated temperature often means there is a problem.

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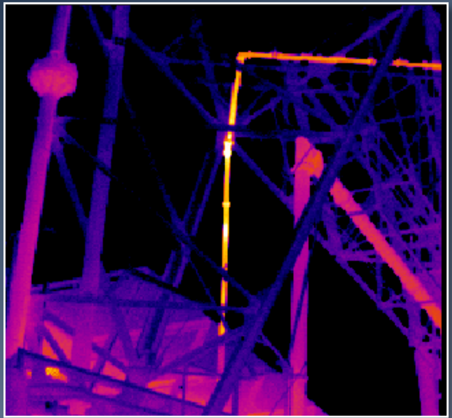
IR Scans – Case Examples

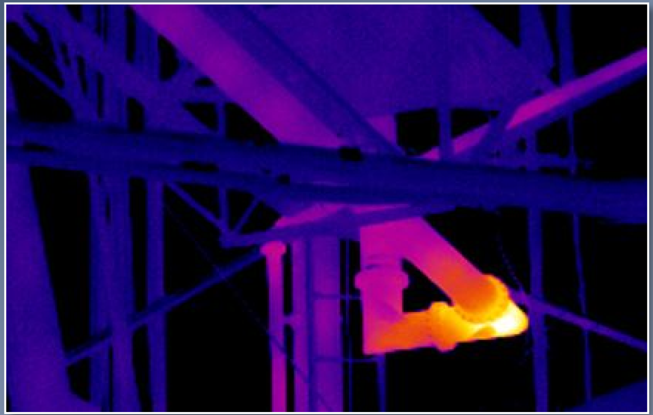
Yes – there really WAS a problem.

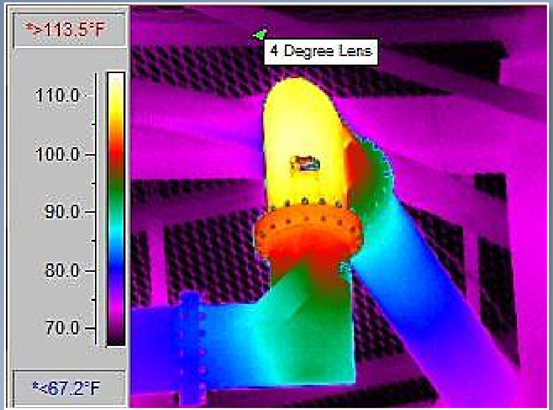
Calling in a Skycrane
is never a cheap date

IR Scans – Case Examples

Here are examples of transmission lines and elbows in trouble







Note that untuned elbows often run slightly warmer than tuned elbows.

The above examples are *way* beyond slightly warm.

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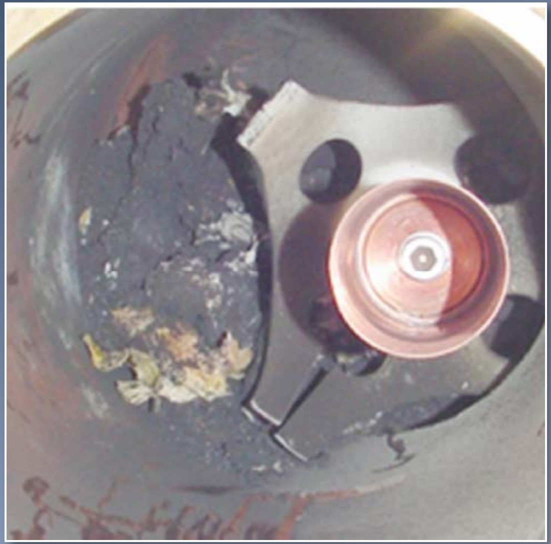
IR Scans – Case Examples

Here are examples of transmission lines and elbows in trouble



I *told you* I was sick!

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IR Scans

Not all brighter images means there is trouble

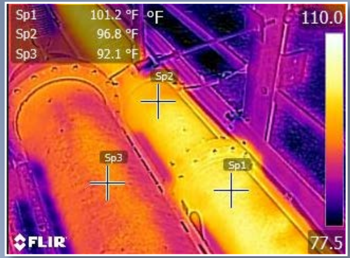
You really need to be careful about what you are imaging and what it means.

Differences in surface finish (color, surface roughness, reflectivity) and even incident light, or heat from an adjoining source can fool you. Sometimes RF can fool the sensor.

Compare the suspect device against a known good device in operation. Find out what sort of temperature rise is normal.

If possible, follow the procedures for accurately determining the temperature, which is not a casual process.

This is where the IR training courses really come in handy.



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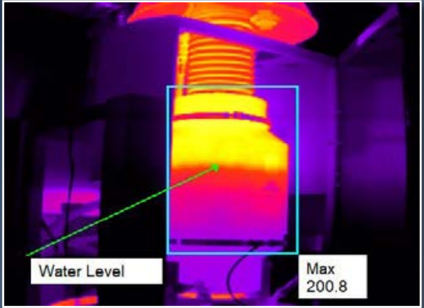
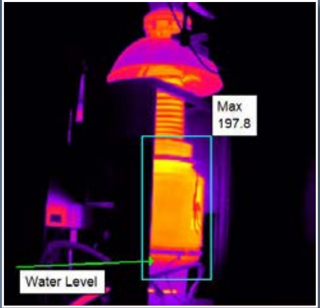
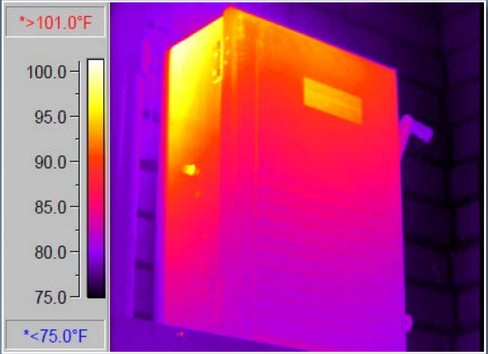
IR Scans as Maintenance Tools

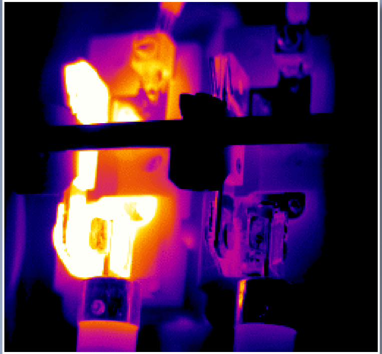
While you are at a site – look around





Water cooled transmitter tubes – one is starting to get in trouble, the other IS in trouble. Look at the coolant levels.





This switch was about to fail. Call the electrician.

CAUTION – follow proper Arc Flash protection around electrical panels

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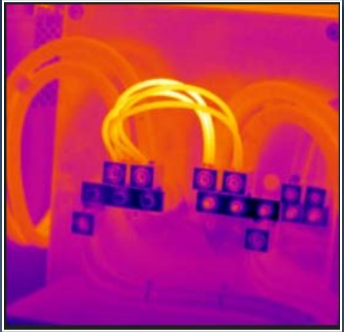
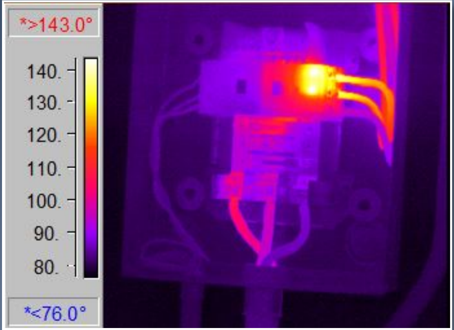
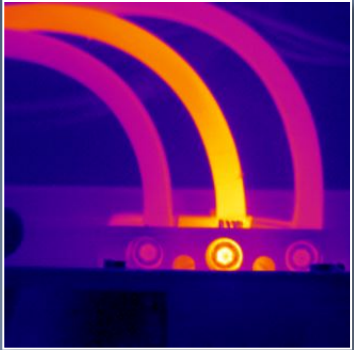
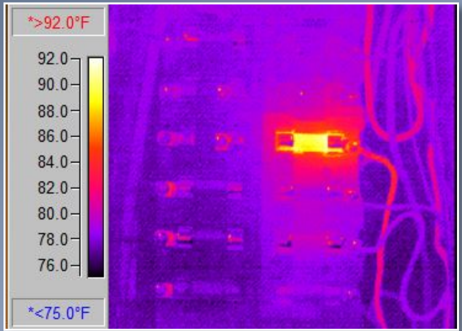
IR Scans as Maintenance Tools

While you are at a site – look around

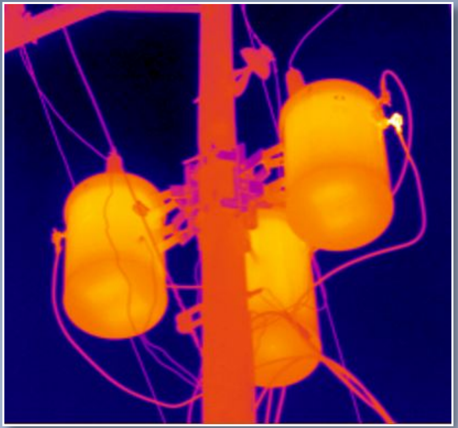








Examples of overloads, connection issues, device issues.



This pole pig connection was about to fail. Call the utility company!

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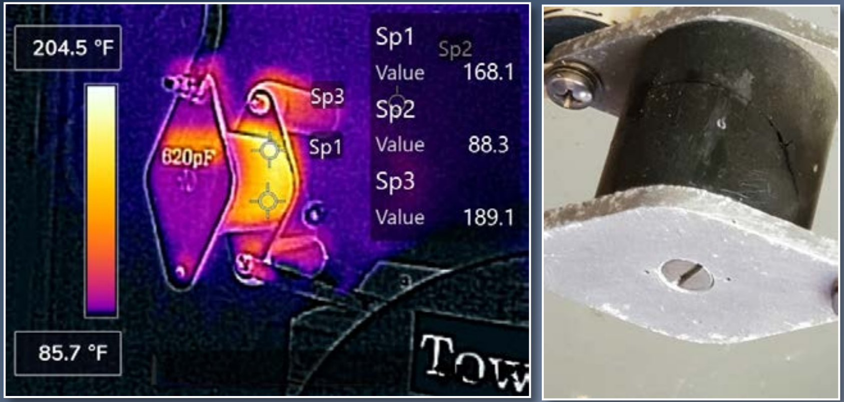
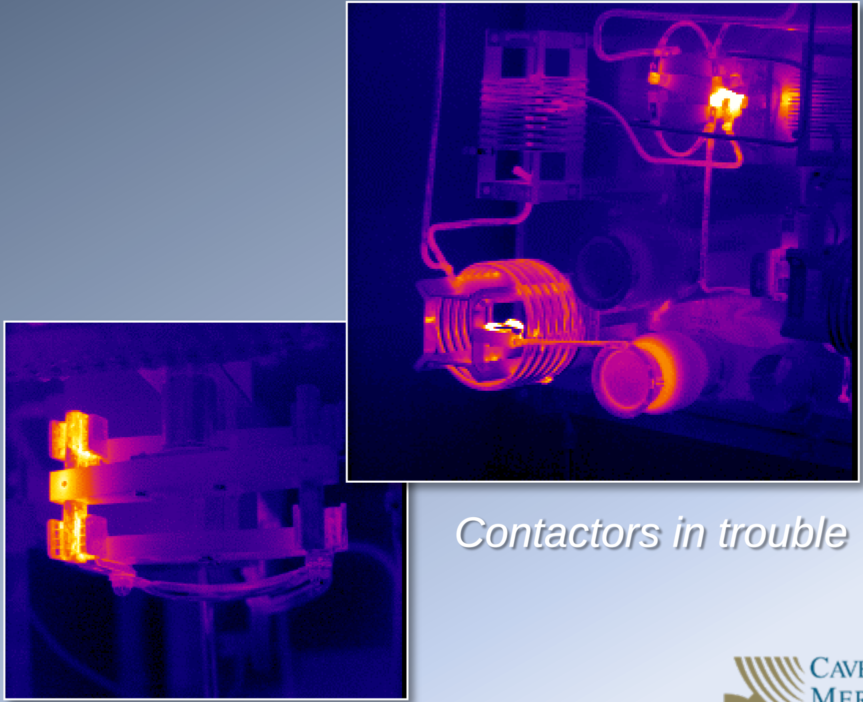
IR Scans as Maintenance Tools

While you are at a site – look around



Mica Cap that has failed



Contactors in trouble

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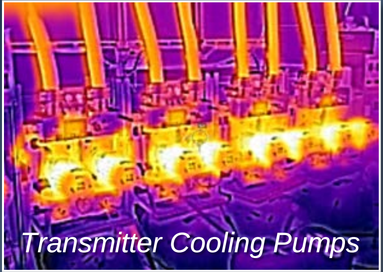
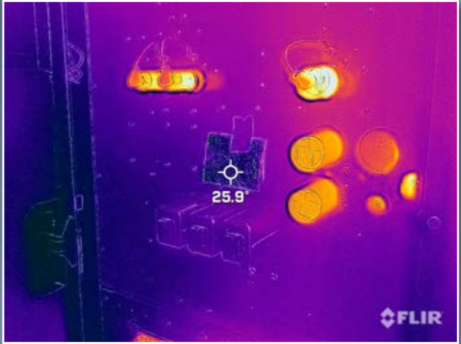
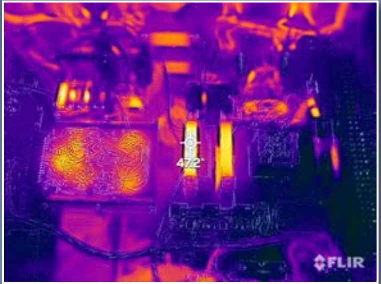
IR Scans

Some things are just neat to look at thermally.



Normal Operating Temps





Can you see the thermographer's heat reflection in this hot cabinet?

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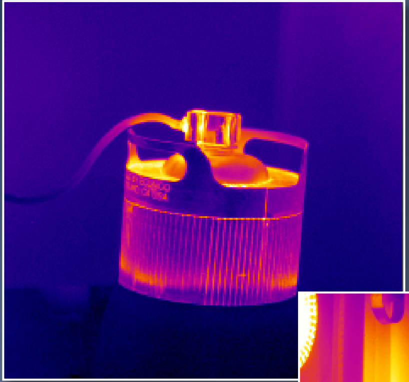
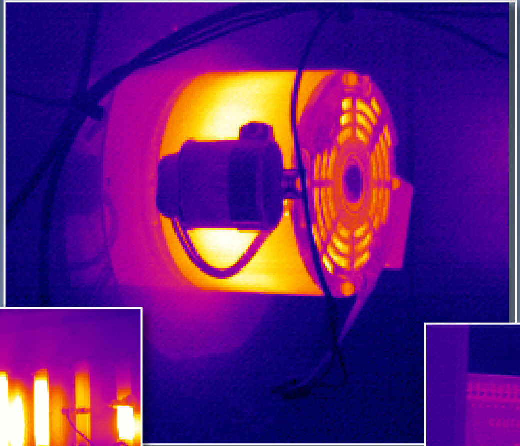
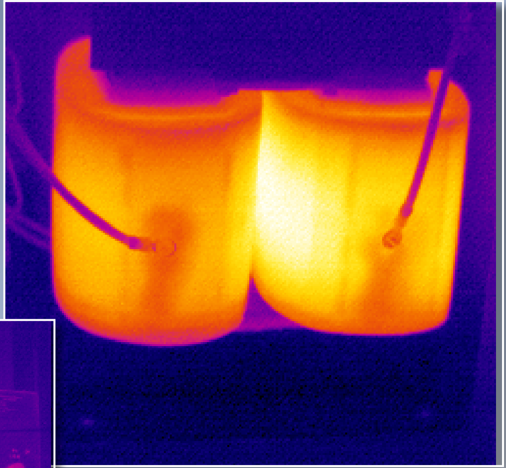
IR Scans

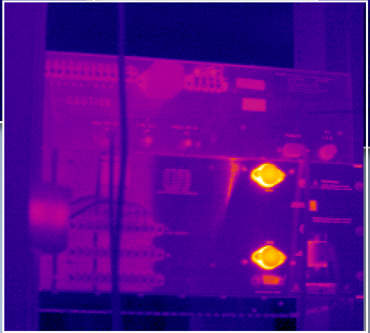
Some things are just neat to look at thermally…

AND you establish a normal operating baseline by doing so!









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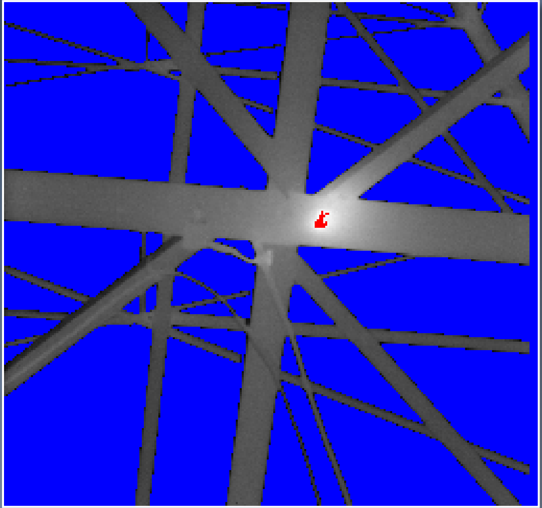
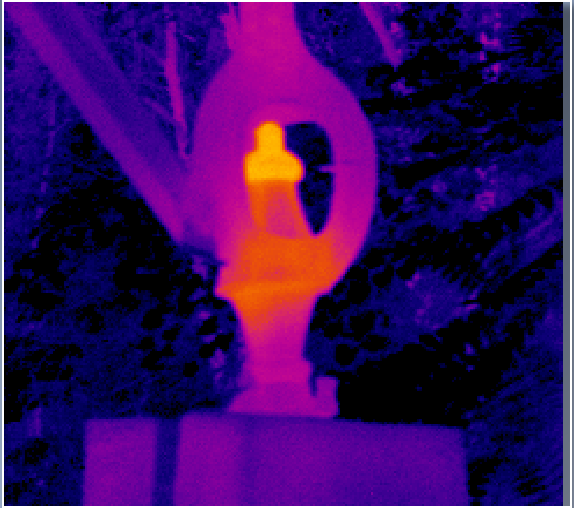
IR Scans

One more interesting one….

sometimes mechanical stress can create a heat signature





Both pictures taken at night –

with no RF energy in the system.

QUESTIONS?