Rig Testing @ July Picnic

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4 Jun 24

Topics

- What, When, Where, How, Why
- Testing
  - Range Equation
  - Transmitter (ERP) Test
  - Receiver (MDS) Test
- Error Contributions
- Interpreting the Results

What When Where

- Each summer, we measure our 10 and 24 GHz rigs at our picnic.
- This is a chance
  - to test your radio before the Aug/Sep contest season
  - to see how other folks built their rigs (transverter, antenna, mount)
  - to see how your rig's performance compares to others'
- We will set up our test range next to the Sandy Wool Lake picnic area at Ed Levin County Park in Milpitas.
- The test/picnic date is Saturday, July 13.
- The park opens at 8am ($6 vehicle entry fee).
- We start testing by 9am and have the picnic afterwards, around noon. The club provides food & drink. You bring sunscreen & hat.
- **Please arrive by 830 or so, to set up your rig and to get aligned on the target, so that we can start by 900 *sharp*.**

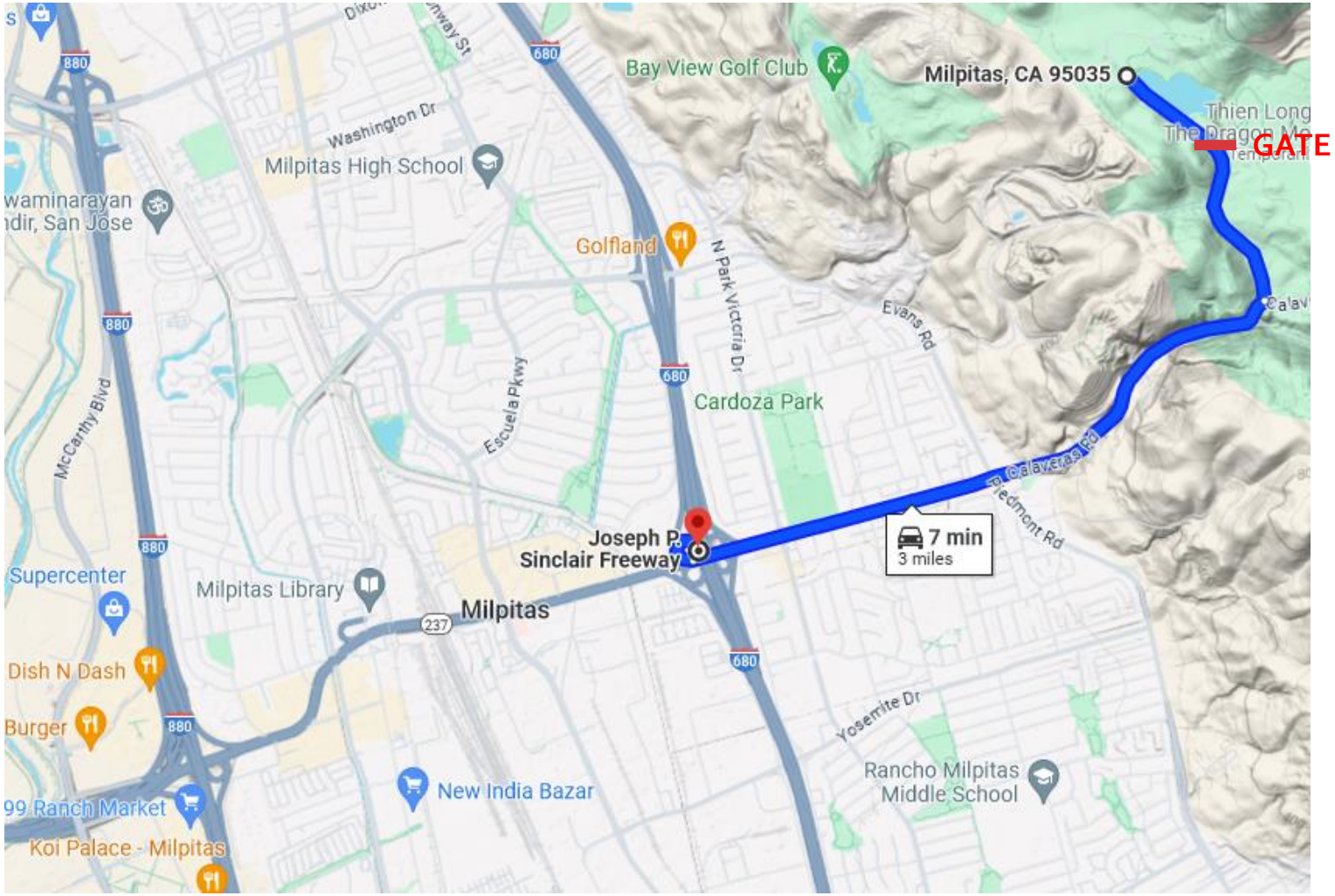
Where:

880 or 680 to Calaveras Blvd (237) in Milpitas…

Calaveras Blvd thru the hills…

Left at the fork onto Downing Rd…

thru gate ($6 fee) to Sandy Wool area



Where
How


Downing Rd
Downing Rd
Downing Rd
~400 ft.
TEST HEAD
FIRING LINE
PARKING
Restrooms
City of Milpitas Dog Park at Ed R. Levin
Sandy Wool Lake - Gazebo
Calaveras Ridge Trail
Calaveras Ridge Trail
Downing Rd
Downing Rd
Sandy Wool
from entry gate

How:

Setup & Prep

- Please arrive by 830 or so, to set up your rig and to get aligned on the target, so that we can start by 900 ***sharp***.
- Park by the row of trees. We will set up cones to mark the 'firing line' on the other side of trees & sidewalk.
- Set up your rig on the 'firing line', facing the test head, which will be transmitting near 10368.1 MHz. (Later, we will also use 24192.1)
- Aim your dish at the test head (**adjust bearing & elevation for peak signal**); also **adjust height above ground for peak signal**.
- **Be prepared to tell me when I ask**:
  - Your name & callsign, what bands (10, 24) you have
  - Your transmitter's expected PA output power on each band
  - Your antenna aperture (height & width) or nominal gain on each band
  - Your transverter's Rx IF frequency (10m, 2m, 432, etc) on each band
- Bring your own power (battery; gas generators not allowed).
- Have a BNC or SMA jack/cable available to hook up to your Rx IF
- Have a way to generate a full power Tx carrier (CW key down).

How:

Running the Tests

- *By 0900, everyone should be peaked on the 10 GHz test source. Be sure you are peaked in Az, El and height and lock it down! **
- We will run four tests, each rig by rig, walking down the line:

1. **10 GHz receiver MDS. I will hook up my SDR to your Rx IF output**** and measure the S+N/N, from which we calculate **MDS10**
2. **10 GHz transmitter ERP.** With test head in Rx10 mode, **I will ask you to send a 'key down' steady CW carrier** to measure your **ERP10**
3. **24 GHz receiver MDS.** *I will switch the test head to Tx24 and send the test signal… everyone will find the signal and re-check antenna height above ground for max strength on the new band.* Again, **I will hook up my SDR to your Rx IF output**** and measure the SNNR, from which we calculate **MDS24**
4. **24 GHz transmitter ERP.** With test head in Rx24 mode, **I will ask you to send a 'key down' steady CW carrier** to measure your **ERP24**

* Try to peak your pointing (Az,El,Z) and keep it locked during each pair of Rx/Tx tests (MDS10 & ERP10, MDS24 & ERP24).

** I will need to know your IF freq & to have SMA or BNC connection

Next: Test Range Model

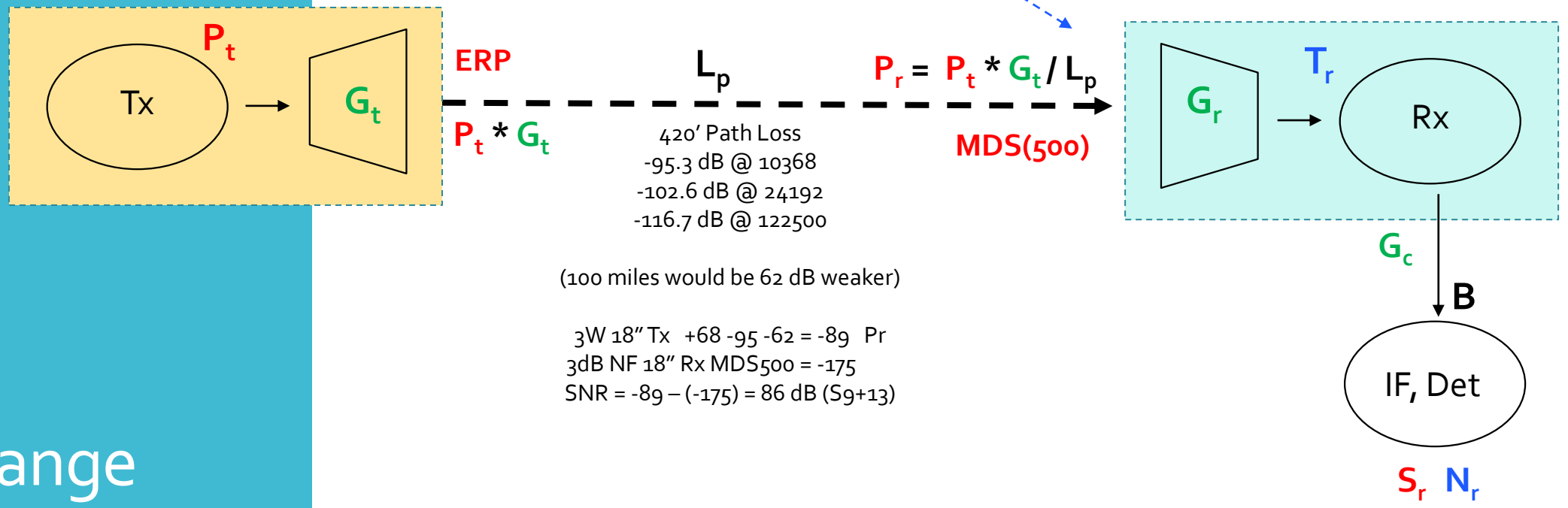
Why:

420’ Test Range Basic Model

and some examples for typical rigs at 100 miles

Some Examples of 10 GHz ERP:
3W, 18” dish -> 37 + 31 -> +68 dBm
10W, 36” dish -> 40 + 37 -> +77 dBm

Some Examples of 10 GHz MDS (500 Hz):
3 dB sys NF, 18” dish -> -147 + 3 - 31 -> -175 dBm
2 dB sys NF, 36” dish -> -147 + 2 - 37 -> -182 dBm



(100 miles would be 62 dB weaker)

3W 18” Tx +68 -95 -62 = -89 Pr
3dB NF 18” Rx MDS500 = -175
SNR = -89 – (-175) = 86 dB (S9+13)

$S_r = P_r * G_r * G_c$ Measured Signal

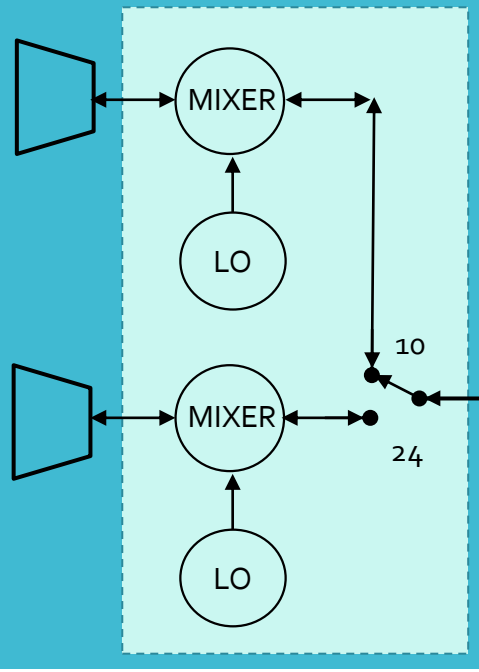
$N_r = k *(T_a + T_r)*B * G_c$ Measured Noise Floor

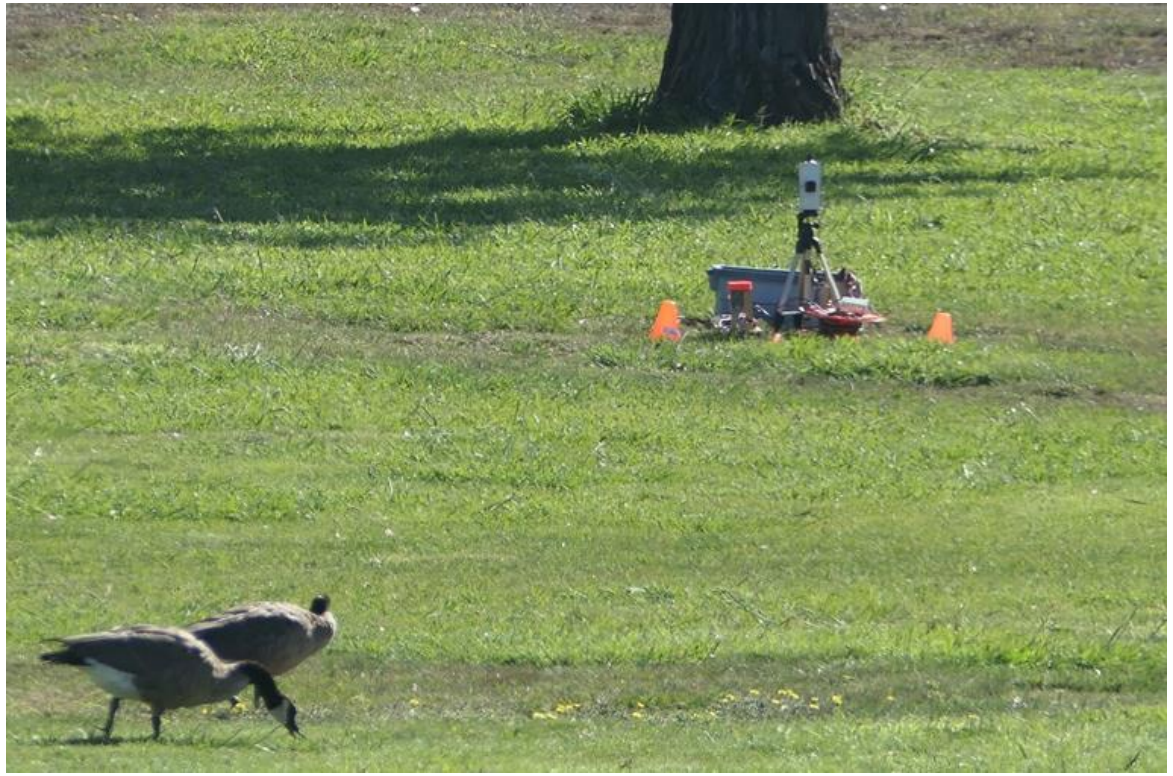
MDS(B) P_r that gives SNR = 1 in Bandwidth B

We can use the ERP and MDS test range results to predict performance over longer LOS paths

Next: Test Head

Remote Test Head

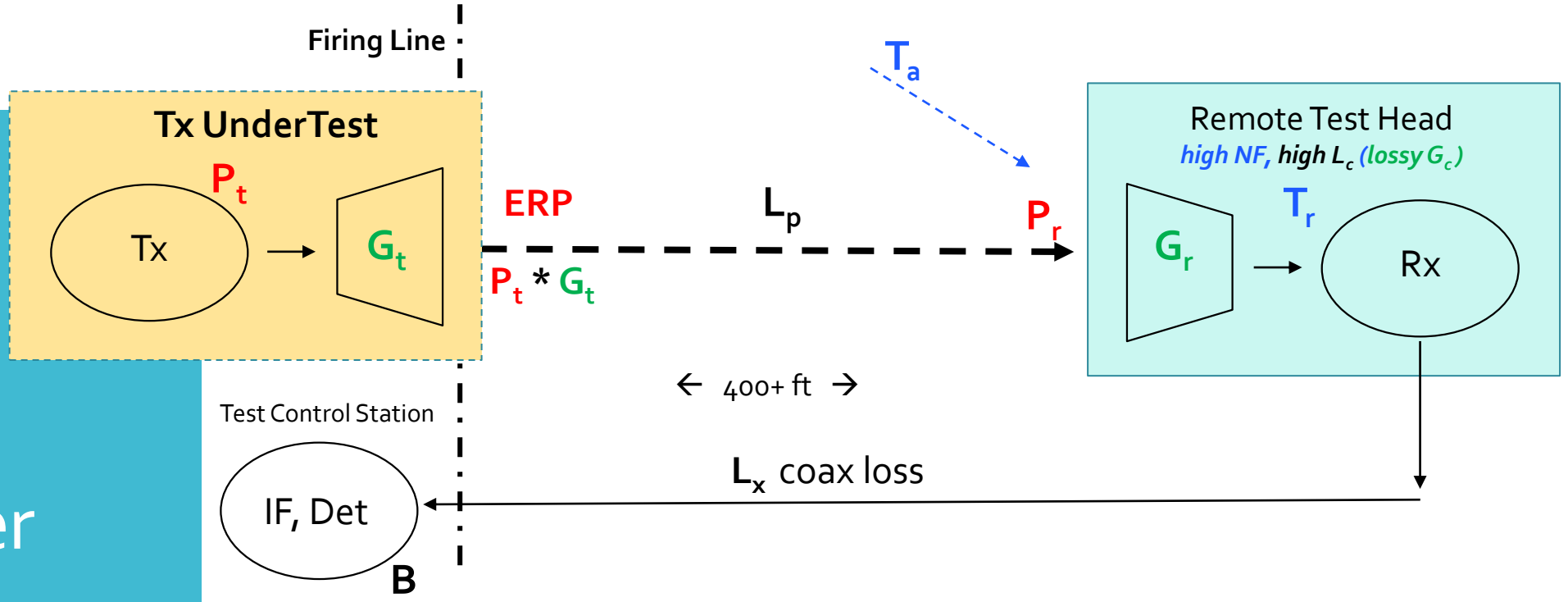




- Test head is a dual band transverter with horn antennas
- At least 400’ away; gives far field up to: 48” 10GHz dish, 30” 24GHz dish
- IF signal thru 450’ of coax back to measurement station on firing line
- Battery powered
- Mounted on small tripod so that rigs under test can be ~5ft off the ground

Next: ERP Test

Transmitter ERP Test

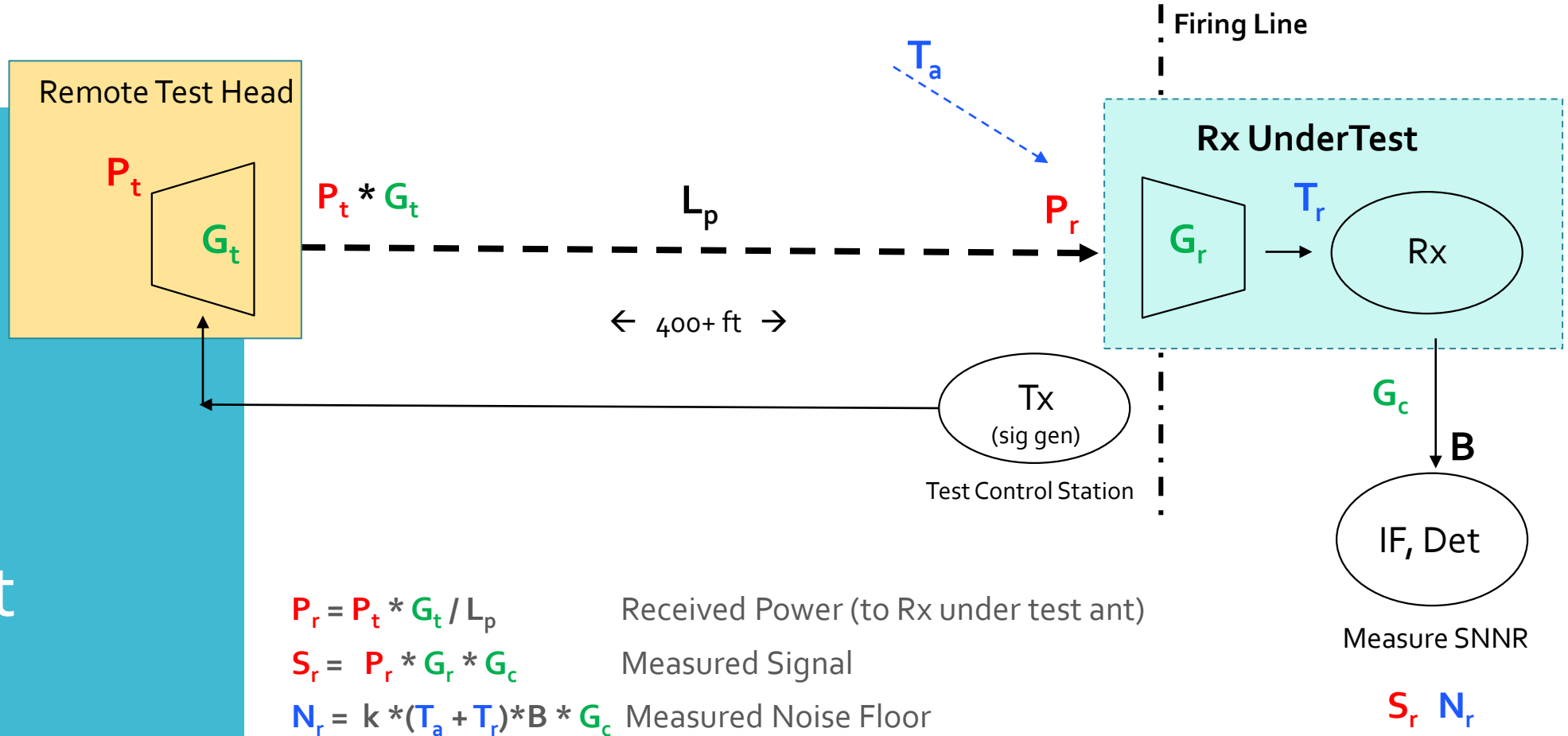


$ERP = P_t * G_t$	Effective Radiated Power (Tx under test)
$P_r = ERP / L_p$	Received Power (to Rx ant)
$S_r = P_r * G_r / (L_p * L_x)$	Measured Signal
$N_r = k * (T_a + T_r + L_x) * B$	Measured Noise Floor ($L_x > T_r > T_a$)

For all but the wimpiest of rigs, $S_r >> N_r$, so can just use S_r and if not, can correct for SNR vs SNNR difference

Next: MDS Test

Receiver MDS Test



$P_r = P_t * G_t / L_p$ Received Power (to Rx under test ant)

$S_r = P_r * G_r * G_c$ Measured Signal

$N_r = k *(T_a + T_r)*B * G_c$ Measured Noise Floor

Previously, we decreased P_t until S_r fell to the noise floor N_r ("Can you still hear me?")
This measurement depended on the owner's hearing and 'grey matter' bandwidth
... very subjective!

Now we use an SDR at a fixed bandwidth **B** , connected to the IF. We measure noise floor N_r and SNNR $(S_r + N_r) / N_r$. Then we calculate SNR (S_r / N_r) and MDS at SNR = 1 $(S_r = N_r)$
... objective measurement of the hardware (and how well it's pointed at the target).

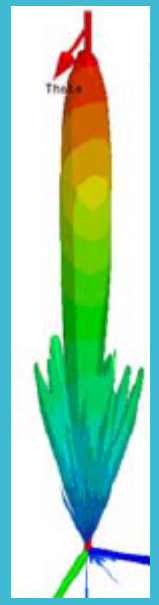
Next: Error Contributions

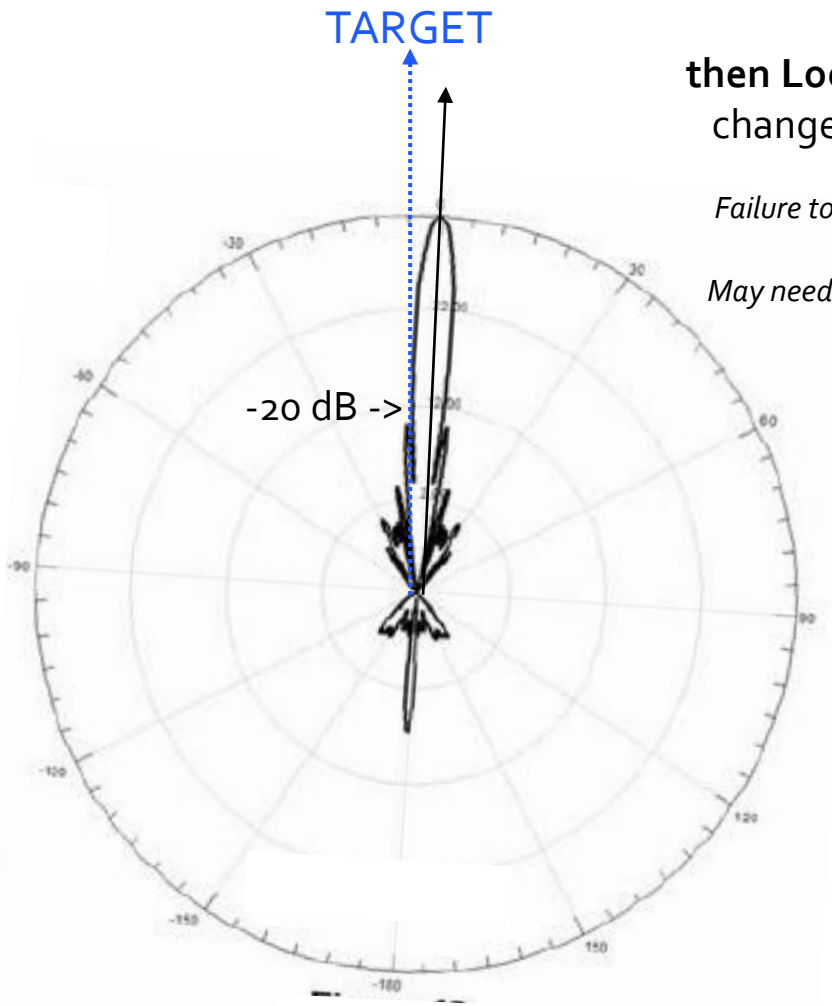
Your antenna & your ability to aim it are key parts of your system!

Aim at the target and **carefully peak & lock dish beam elevation and azimuth**
A few degrees error in either direction can cost **10 or more dB** MDS & ERP!!!
(This is true during field operations as well as on the test range)

> 10 dB Errors:

Poor Antenna Pointing





Peak *before* MDS test starts,
then Lock your mount's El & Az so that it won't change during or between MDS and ERP test

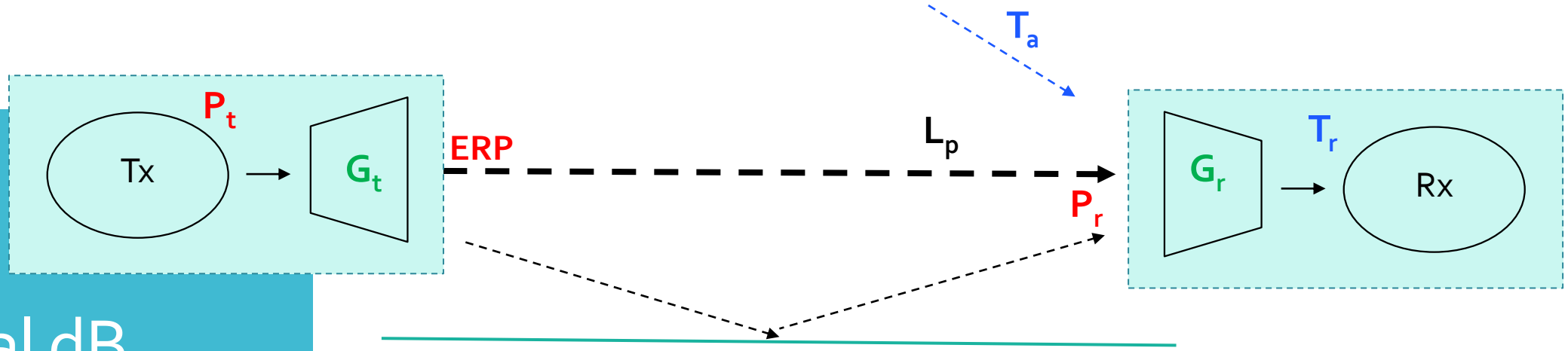
Failure to lock can result in loss of peaking, hurts 2nd(ERP) test

May need to repeak height, then El-Az, when we change bands

Some Peaking Tips:

- Turn off your AGC, reduce RF gain, listen for peak audio (full quieting)
- Opening up bandwidth and/or tuning slightly off frequency can mix in some crackly background noise (AM or FM mode) for contrast with the signal, but remember to get back on frequency when done.
- I will have a portable audio voltmeter that you can use if you don't trust your ears. It plugs into 1/8" headphone jack (turn your AGC off)

A great way to shoot yourself in the foot!



Several dB Errors:

Test Range Ground Reflection Gain/Loss

For a ***perfect*** ground plane (metal sheet), P_r will be **+6dB greater** if reflection is exactly **in phase** and P_r will be **zero** (cancelled) if reflection is exactly **out of phase**. But ***real*** ground is lossy (grass, dirt) and uneven, so P_r is considerably less than +6dB greater when peaked/in phase.

We try to choose the test head antenna height so that the reflection path will be in phase at a reasonable rig under test tripod height (~5 feet).

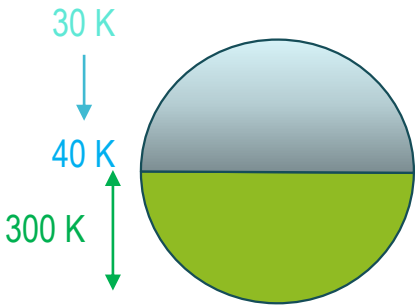
Assuming that all rig antenna heights are adjusted to one of the in phase reflection peaks and a fairly even test range surface, the effect of ground reflection is a slight ground gain (about 1-3 dB), about the same for all rigs. This is a calibration error for absolute measurements, but should have no impact on relative results.

If you have an up/down crank and clutch on your tripod head, **you can minimize reflection error by adjusting your tripod height for peak signal & locking at that height***. If you don't, find a neighbor who does, observe (center) dish height of his El-Az-Z peaked dish, **copy** that height to yours by adjusting your tripod leg lengths*.

* **<u>After peaking in height, you will need to (re)peak in El-Az.</u>** *(rinse & repeat)*

Fewer dB Errors:

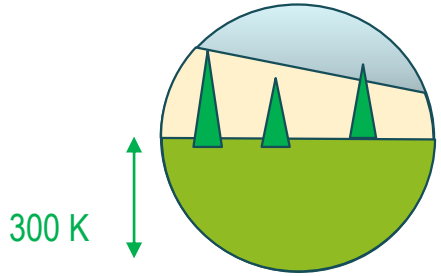
Antenna Noise Temperature



Average: **Ta ~ 170 K**

Clear Field
Terrestrial Operation

Antenna
FOV to
Horizon

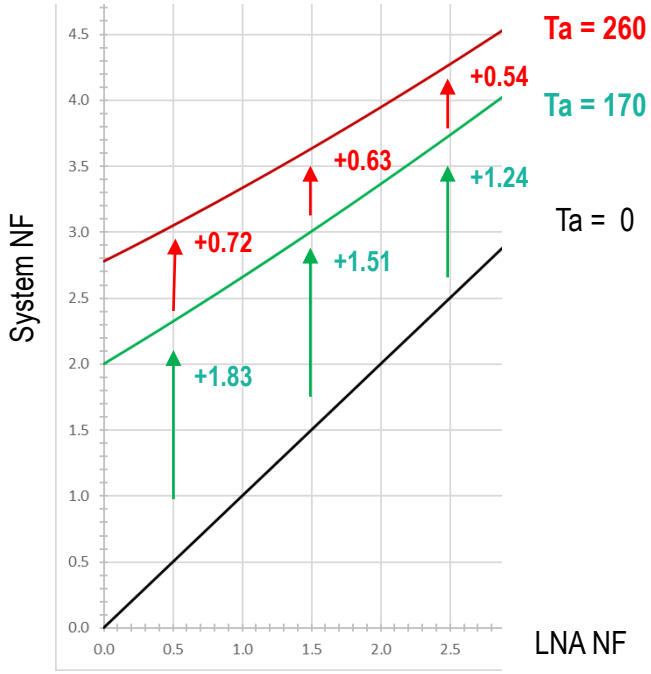


Average: **Ta ~ 260 K**

Test Range Clutter
Behind Test Head

Ground noise increases Ta in terrestrial operation

Increases system NF; more impact on better LNAs



Additional test range background clutter increases Ta some more

So we see some additional sys NF compression

Error Contributions

Error Factor	dB	Can User Avoid?	Comments	Real?	Cal?	Rank?
Pointing (El, Az)	> 10	***YES!*** Peak carefully & lock	Pointing errors can reduce your antenna gain dramatically	**Y!**	Y	Y
Ground Reflection	1..3+	Yes, adjust height per band	Slight decrease in "range loss", loss of ERP, MDS calibration	N	Y	N*
Firing Line Position	< 1	Slight advantage in center?	Not significant	N	Y	Y
Not in Far Field	varies	Dish too large for range = Dish gain error		N	Y	Y
Ground Noise	1~2	Raised noise floor, MDS compression among best LNAs		Y	Y	N
Background Noise	<1	Raised noise floor, BG clutter = more MDS compression		N	Y	N
Dynamic Range	varies	Extremely high ERP may saturate test system OR Extremely low ERP/high MDS may approach the noise floor		N	Y	N
Human Perception	0	We used to measure MDS by ear, now we use SDR to measure S_r and N_r		N	N	N

Bottom line:

The tests are fairly realistic and produce a reasonable relative ranking, but have several dBs of absolute error and dynamic range limits. Some of that error can be removed using the 'wisdom of the crowd' (use the units that preform close to expectations to 'calibrate' the test).

Interpreting Results

Triage

Compare your results to:

- Expected results (based on your PA power, antenna gain and reasonable Rx NF)
- Wisdom of the crowd ('calibrate' to the rigs that came closest to expectations)

1. **If MDS and ERP shortfalls are same** (or close to same):
   - Problem impacts Tx and Rx ~equally --- in the common path
   - ***First, are you sure that you were pointed correctly (El, Az, Z)?***
   - If yes, antenna problem (feed, focus, feedline) or T/R switch (antenna port)
   - Cables & connectors in common path (lossy, broken, intermittent)
   - If total failure in MDS & ERP … power supply, power cables
2. **If significant MDS shortfall**, but ERP on target
   - Rx side problem: T/R sw Rx port, Rx feed from T/R switch, LNA, downconverter, etc
   - Cables & connectors in Rx path
3. **If significant ERP shortfall**, but MDS on target
   - ***First, are you sure that your dish did not move between MDS and ERP test?***
   - If not, Tx side problem: T/R sw Tx port, Tx feed from T/R switch, PA, upconverter, etc
   - Cables & connectors in Tx path
   - Power supply sagging during high Tx load … cables, battery
4. **If shortfalls in both MDS and ERP & significantly unequal**
   - Maybe more than one issue …
   - The smaller shortfall might be in the common (antenna) path [see 1 above]
   - The additional shortfall in MDS or ERP could be in Rx or Tx path [see 2 or 3, respectively]

Summary

Come to the rig testing at the July picnic:

- Check that your rig (still) works
- Learn about it's strengths and weaknesses
- Diagnose problems
- Learn how others built their rigs & how well they work
- Tests are realistic & relatively accurate, not super calibrated
- Tests measure overall system performance, not components
- Be set up, peaked & locked on target by 0900
- Come prepared and know the drill, so we can get the tests done in less time and more accurately
- Then enjoy the picnic

Thank you