ATHENS AMATEUR RADIO CLUB

RADIO SYSTEM INSERTION LOSS ANALYSIS

FEBRUARY 21, 2026

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FULL DISCLOSURE

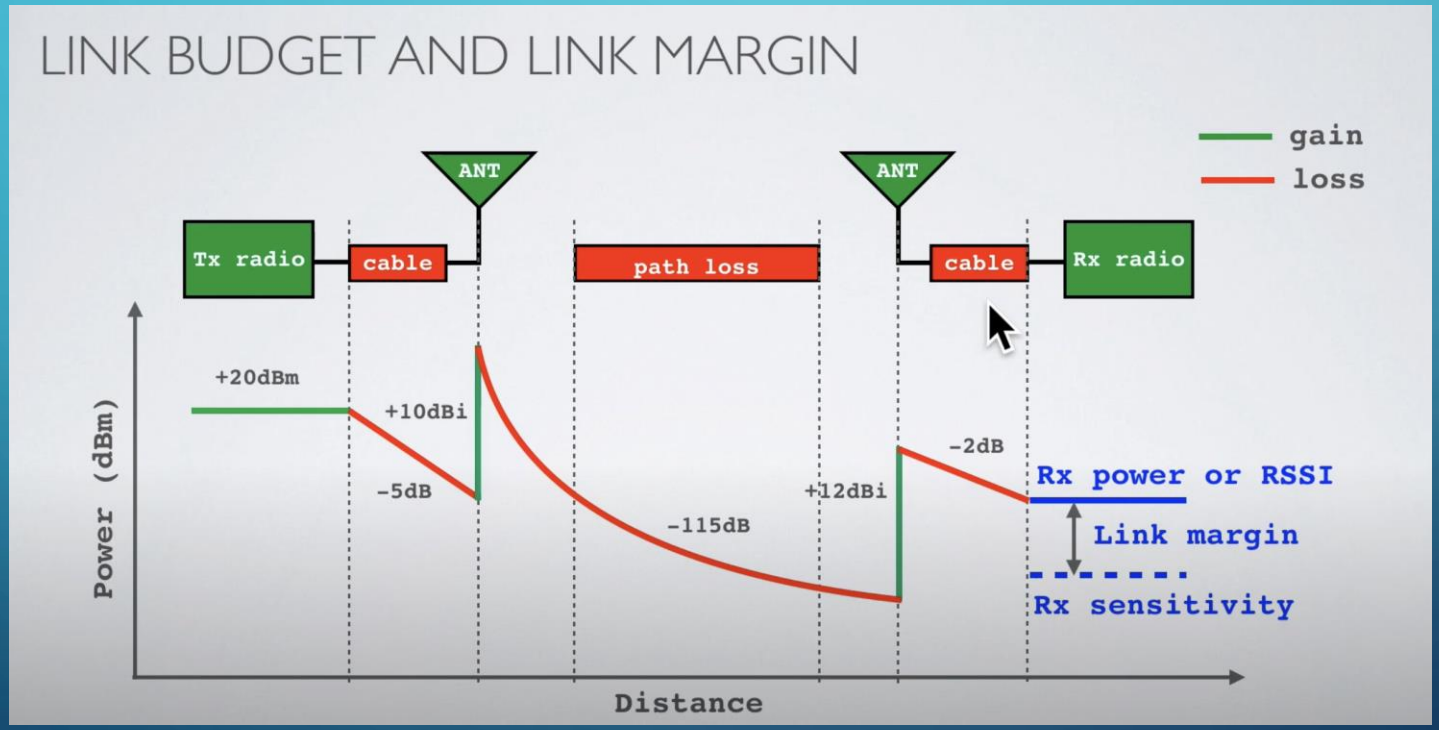
- This presentation has largely been created by the use of ChatGPT!
- ChatGPT is a powerful tool using AI to save hours of research and detail including topic points, analysis, and various images.
- Of course there are other AI tools that are probably as effective.
- However, not all AI information is accurate due to its information source!
- It is amazing (and perhaps a little scary) to see the technological advancements that are happening at such a rapid pace.

TOPICS FOR DISCUSSION IN THIS PRESENTATION

- Introduction
- Definition of Insertion Loss
- Practical Insertion Loss concepts for HF/VHF/UHF amateur radio
- Typical Component Insertion Losses
- Analysis based on real-world station design & troubleshooting

INTRODUCTION

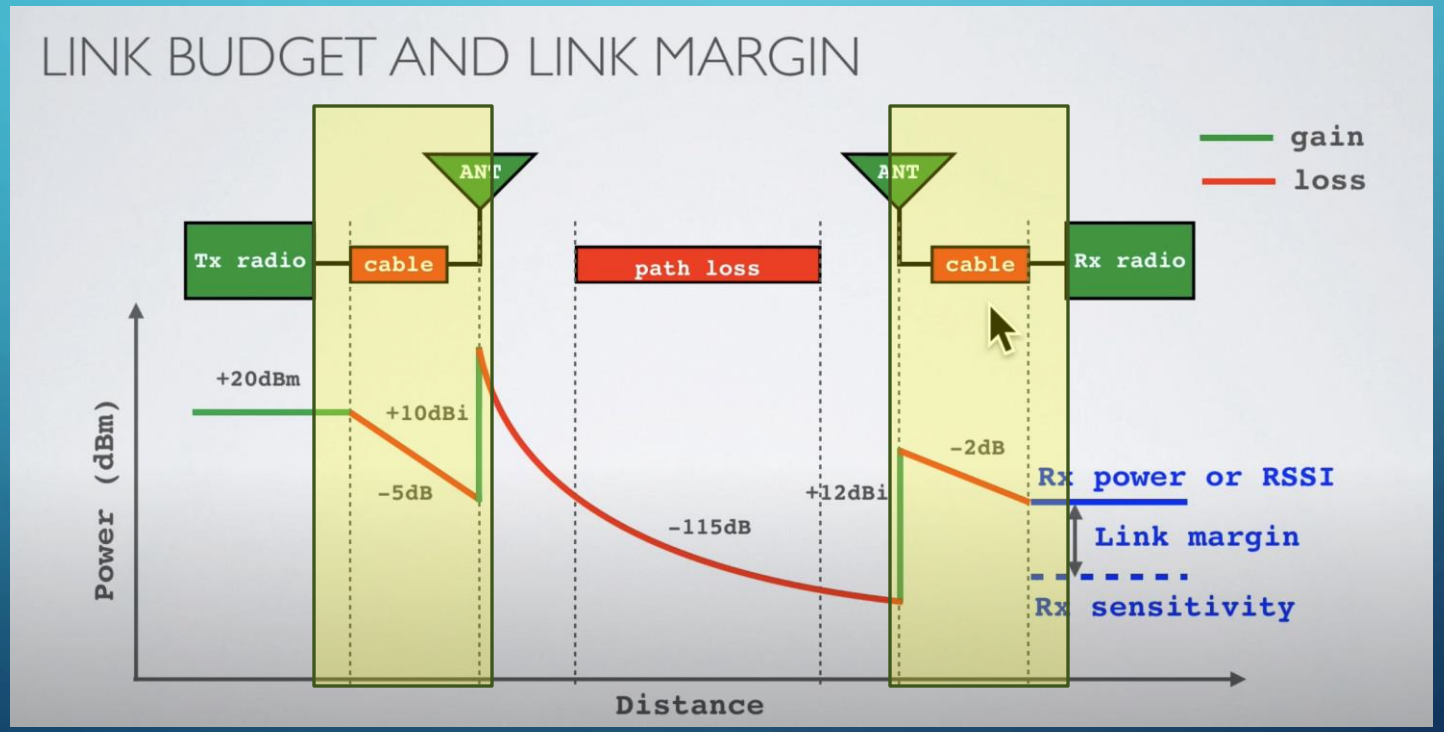
There are a couple of new questions introduced on the most recent General Class License Exam that cover a link budget analysis, specifically Link Budget and Link Margin.



https://www.youtube.com/watch?v=jMFa3AiDbcI

INTRODUCTION

For today's presentation, I am only going to discuss the things we have control over, meaning the different components of our amateur radio station and the losses referred to as Insertion Loss.



WHAT IS INSERTION LOSS?

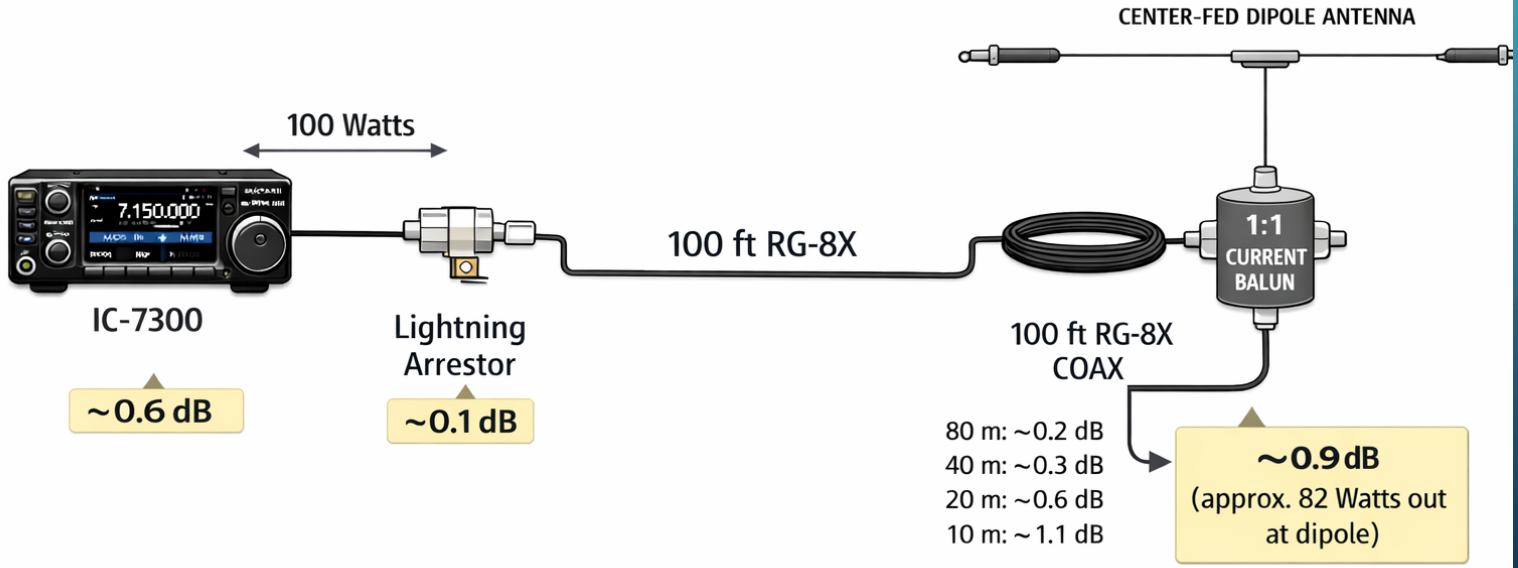
- **The general concept of insertion loss involves introducing something into a path that changes the expected result.**
- Consider taking a trip from here to Dallas. For planning purposes, you want to know when to leave to get there by a certain time so you check your phone.
- Do you accept that time at face value? No, because you know things happen between here and there that could slow you down. Perhaps there are stop lights along the way or an accident occurs or it starts to rain, or there is construction, or …
- Those things **inserted** along your path reduce your ability to arrive at the expected time.

WHAT IS RADIO SYSTEM INSERTION LOSS?

- Radio System Insertion Loss is the reduction in signal power caused by inserting a device or devices into the RF path.
- Expressed in dB: Insertion Loss = 10 log10(Pout / Pin)
- Lower is better. At HF, even 0.5 - 1 dB matters, especially on receive.
- How do we relate to dB loss from the standpoint of % of power lost?

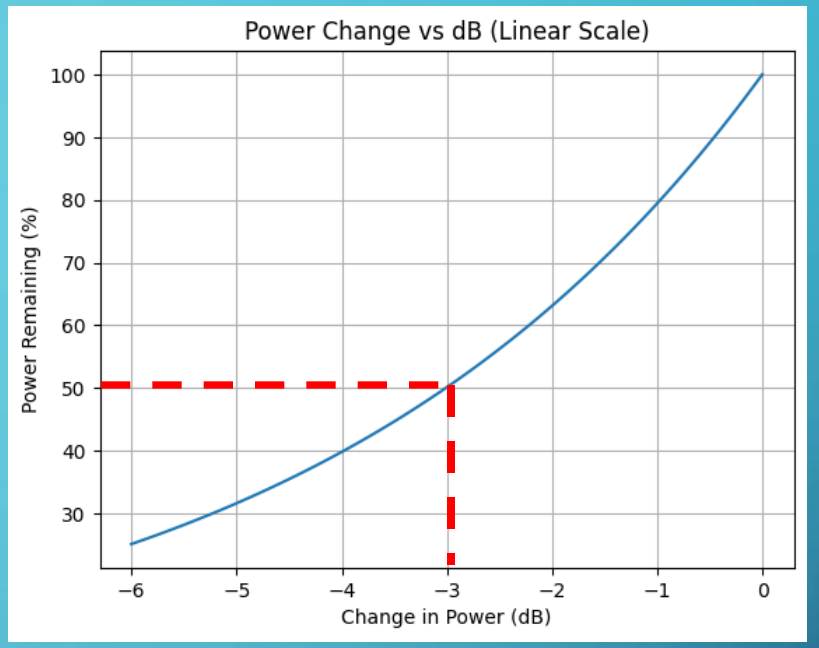
ALL SYSTEMS HAVE SOME INSERTION LOSS

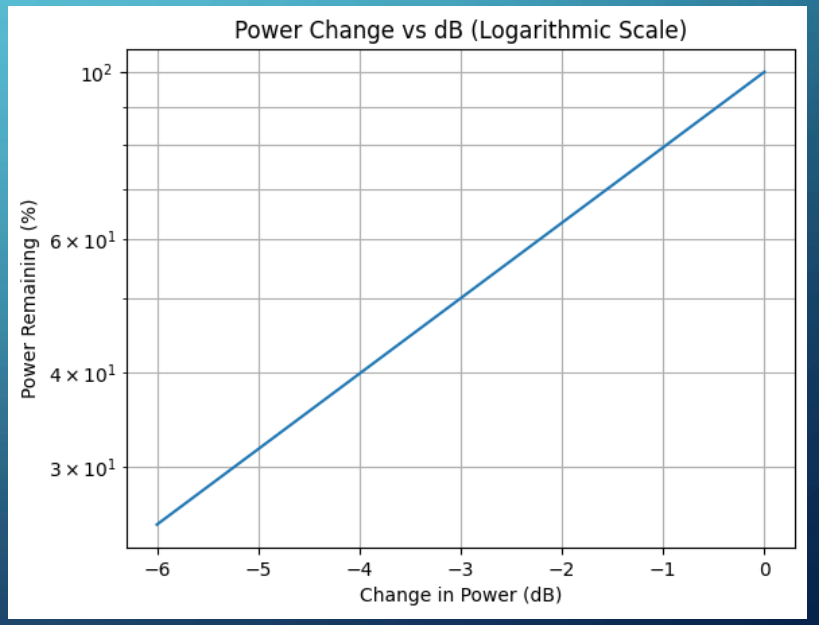
- **HF bands → Icom 7300: 100 Watts**
- **Total insertion loss: ~0.9 dB** (approx. 82 Watts out at dipole)



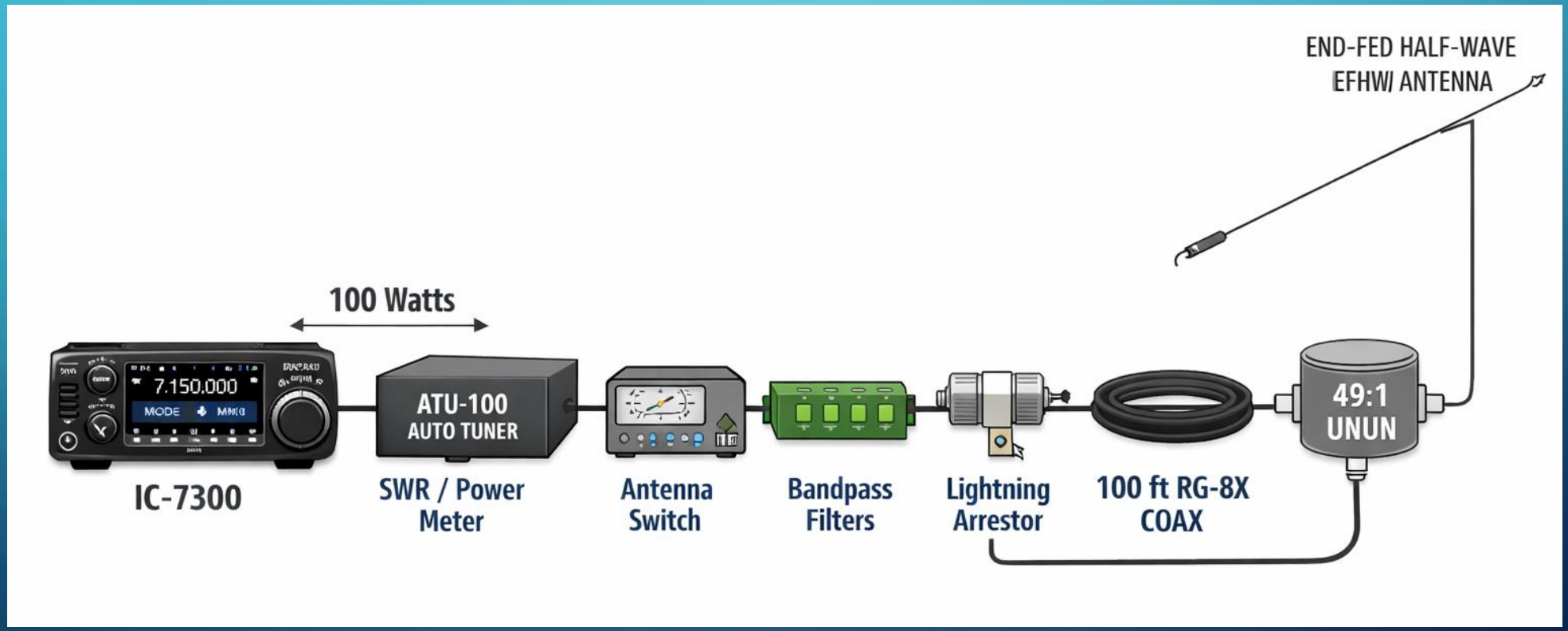
dB CHANGE VERSUS % CHANGE

Percentage of lost or gained signal per dB					
dB Change	% Change	dB Change	% Change	dB Change	% Change
0.1	2.28	1.7	32.4	3.3	53.2
0.2	4.5	1.8	33.9	3.4	54.3
0.3	6.67	1.9	35.4	3.5	55.3
0.4	8.8	2	36.9	4	60.2
0.5	10.9	2.1	38.3	5	68.4
0.6	12.9	2.2	39.7	6	74.9
0.7	14.9	2.3	41.1	7	80
0.8	16.8	2.4	42.5	8	84.2
0.9	18.8	2.5	43.8	9	87.4
1	20.6	2.6	45	10	90
1.1	22.4	2.7	46.3	11	92.1
1.2	24.1	2.8	47.5	12	93.7
1.3	25.9	2.9	48.7	13	95
1.4	27.6	3	49.9	14	96
1.5	29.2	3.1	51	15	96.8
1.6	30.8	3.2	52.1	20	99



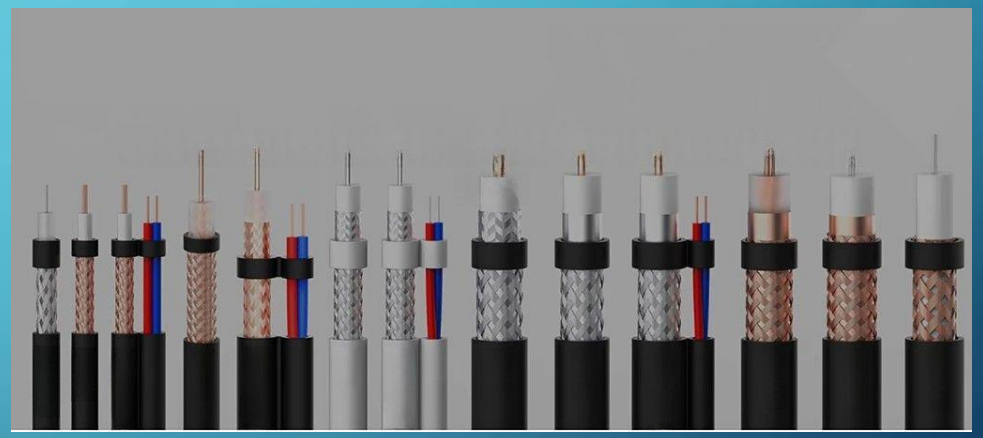


EXAMPLE OF COMPONENTS THAT MAY CONTRIBUTE TO INSERTION LOSS



TYPICAL COMPONENT INSERTION LOSSES
COAX CABLE

- Approximate loss @ 30 MHz per 100 ft:
  - RG-58: ~1.5 – 2.5 dB
  - RG-8X: ~1.2 dB – 2 dB
  - RG-213 / RG-8: 0.6 – 1 dB
  - LMR-400: ~0.4 – 0.7 dB
- At 7 MHz, losses are ~⅓ or less.
- Loss is proportional to length, so a 50’ cable would have half the loss.
- Quality of the manufacturing process is a factor. **Check their specifications!**



COAX CABLE LOSS TABLE

Attenuation in dB per 100 feet							
Cable Group	30 MHZ	50 MHZ	100 MHZ	150 MHZ	450 MHZ	1000 MHZ	2400 MHZ
LMR-100A®	3.9	5.1	7.2	8.9	15.8	24.1	38
LMR-200®	1.8	2.3	3.2	4	7	10.4	16.5
LMR-240 Ultra®	1.3	1.7	2.9	3.6	5.3	9.5	12.7
LMR-240®	1.3	1.7	2.4	3	5.2	7.9	12.7
LMR-400 Ultra®	0.8	1.1	1.5	1.5	3.2	5	7.9
LMR-400®	0.7	0.9	1.3	1.5	2.7	4.1	6.6
RG-174	5.5	6.6	8.8	10.3	18.1	27.4	43
RG-213	1	1.5	2.1	2.8	4.4	7.1	12
RG-214	1.2	1.6	1.9	2.4	5.1	8	13.7
RG-316	4.3	5.6	7.9	4.4	17.2	26.1	45
RG-58A/U	2.5	4.1	5.3	6.1	10.6	24	38.9
RG-8/U FOAM	1	1.2	1.8	2.4	4.4	7.1	12
RG-8X	2	2.1	3	4.7	8.6	12.9	21.6
RG218/U	0.4	0.6	0.8	1	2	3.8	6.4

TYPICAL COMPONENT INSERTION LOSSES
CONNECTORS & ADAPTERS

- PL-259 / SO-239 (good): 0.05 - 0.1 dB each
- Cheap or corroded adapters: >0.3 dB
- BNC Connectors: 0.2 dB each
- SMA Connectors: <0.1 dB each
- Chains of adapters add up quickly.

TYPICAL COMPONENT INSERTION LOSSES
ANTENNA TUNERS

- Matched antenna: 0.2 - 0.5 dB
- High antenna mismatch: 1 - 3 dB+
- Loss increases with:
  - High circulating currents caused by large amounts of reactive impedance
  - Low-Q inductors
  - High SWR at tuner input
- Matching at the antenna beats matching in the shack.

TYPICAL COMPONENT INSERTION LOSSES
BALUNS & UNUNS

- Good current balun: 0.3 - 0.6 dB
- Voltage balun (unun): 0.5 - 1.5 dB
- Poor core choice: 2+ dB & heating
- Wrong impedance ratio = high loss.

TYPICAL COMPONENT INSERTION LOSSES
FILTERS, SWITCHES & RELAYS

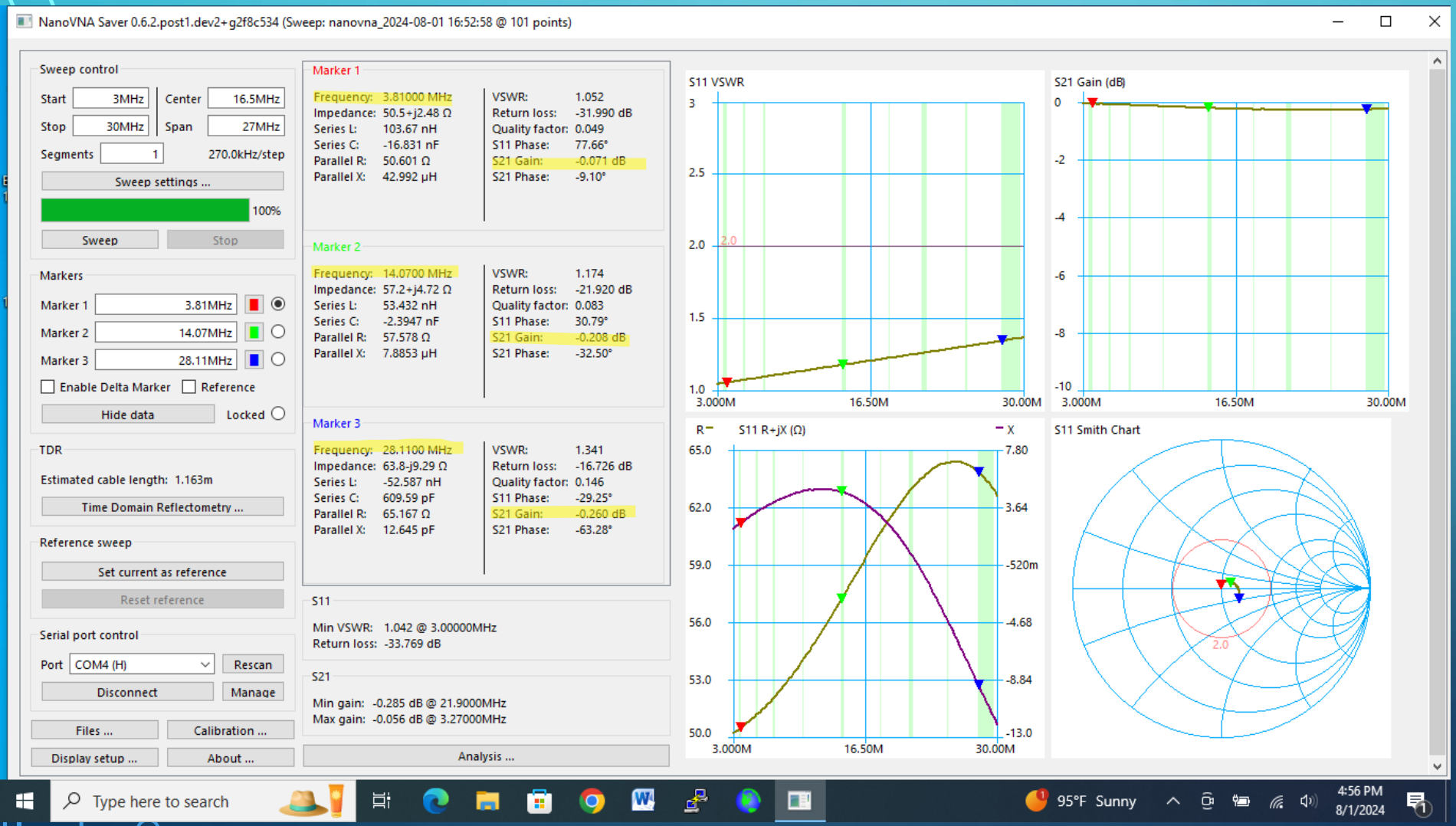
- LPF/BPF: 0.1 - 0.4 dB
- Multi-band filters: up to 0.6 dB
- RF relays: <0.1 dB
- Antenna switches: 0.1 - 0.2 dB

HOW CAN WE MEASURE INSERTION LOSS

- Best:
  - VNA (NanoVNA): measure S21
  - Signal generator + power meter
  - On-air A/B tests (comparing two different pieces of equipment)

- Warm devices & wide tuning ranges usually mean loss.

VNA MEASUREMENT OF INSERTION LOSS



Using a NanoVNA to measure characteristics of a 1:1 Balun (Choke)

TRANSMIT VS RECEIVE IMPACT

- TX: 1 dB loss → 100 W becomes 79 W (often masked by propagation)
- RX: 1 dB loss directly reduces SNR
- **Receive loss matters more for weak-signal DX.**

MY HF STATION DIPOLE EXAMPLE

Radio w/Internal Tuner:
~0.6 dB

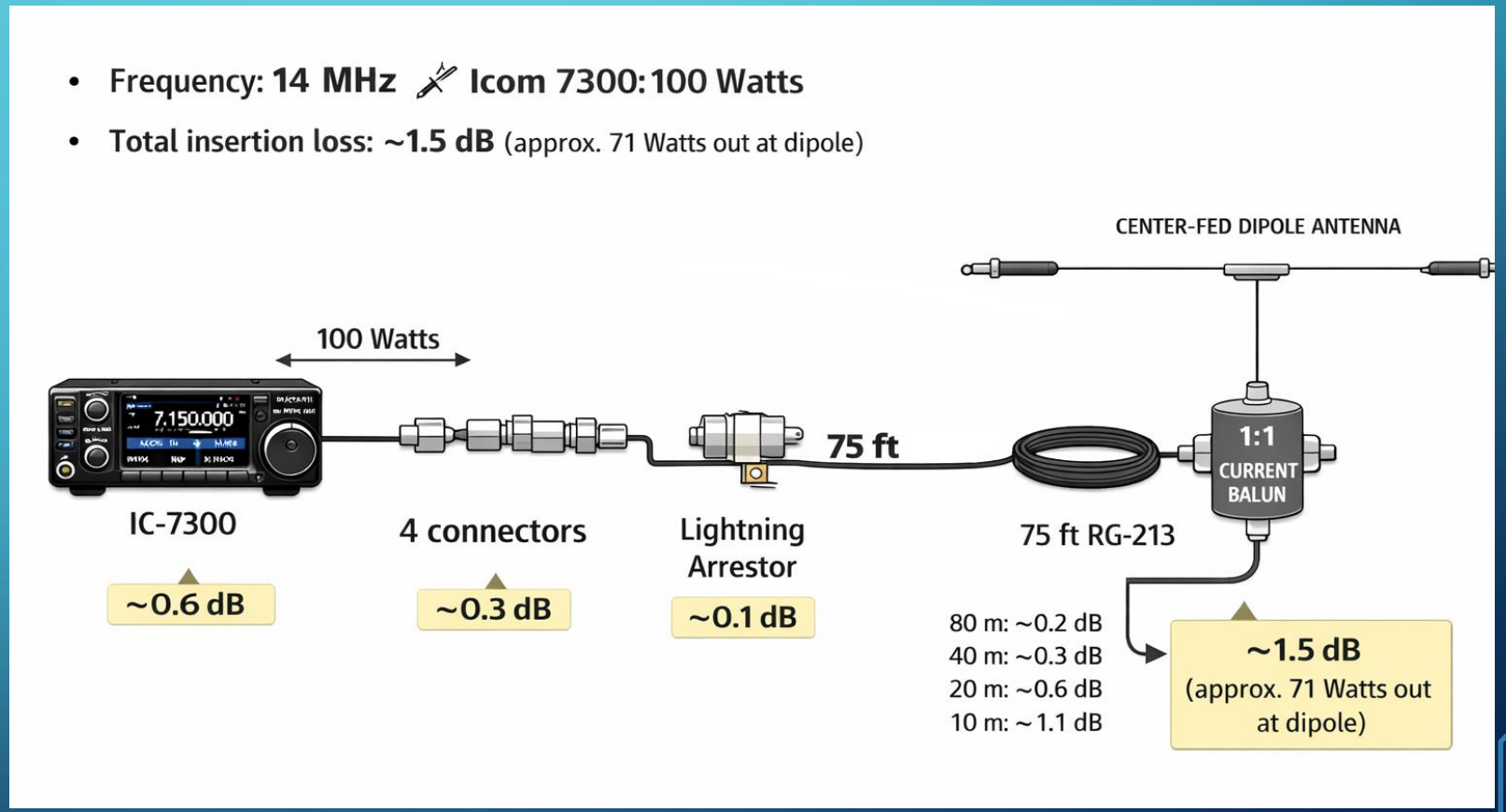
4 connectors: ~0.3 dB

Lightning Arrestor: ~0.1 dB

75 ft RG-213 @ 14 MHz:
~0.3 dB

Balun: ~0.3 dB

Total ≈ 1.5 dB
(~30% power loss)



MY HF RADIO SYSTEM EFHW EXAMPLE

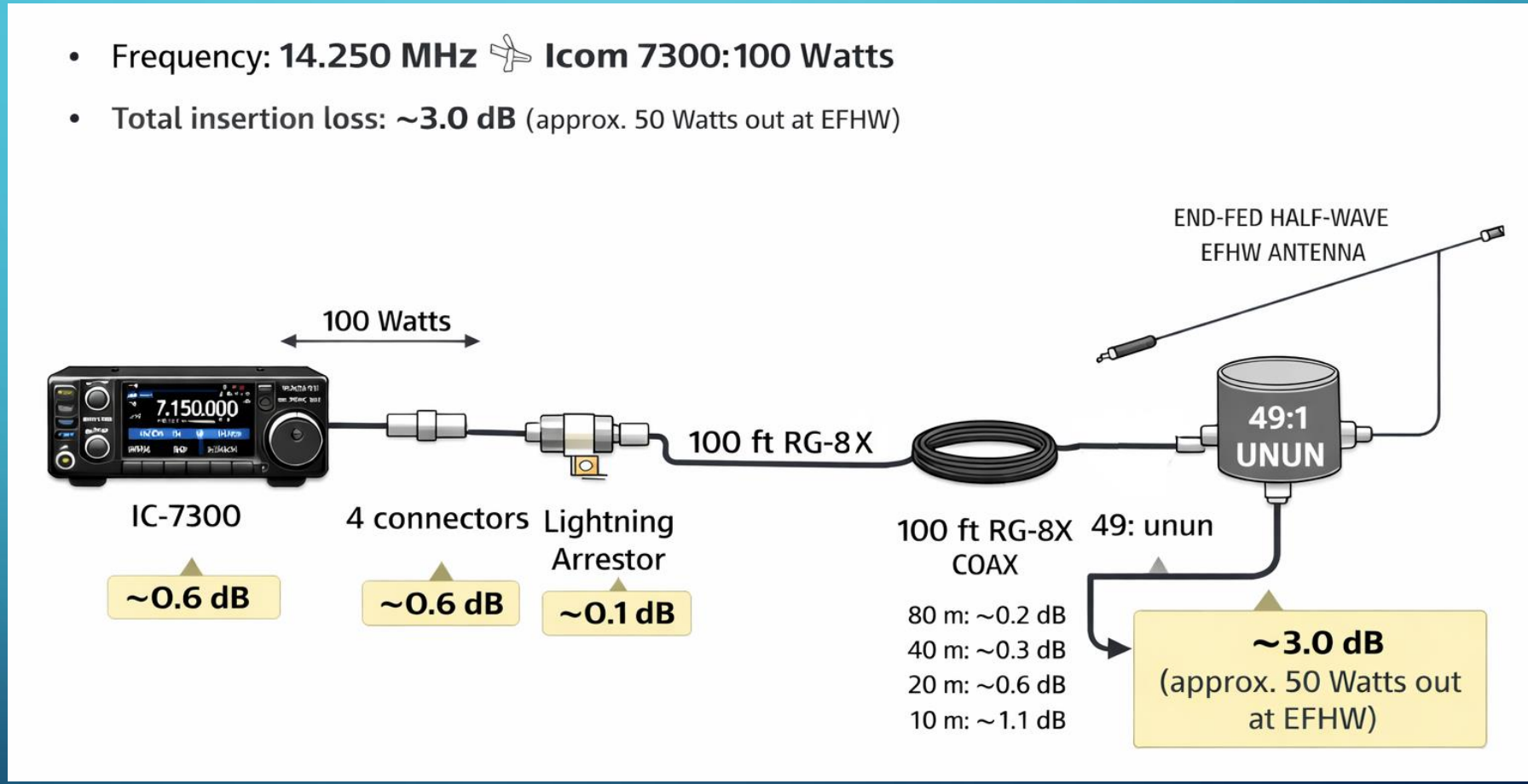
Radio:

ICOM IC-7300 @ 100 W

Antenna: EFHW with 49:1 UNUN

Coax: 100 ft RG-8X

Bands: HF



TOTAL SYSTEM LOSS COMPARISON

- EFHW (20 m): ~3.0 dB (~50 W radiated)
- Center-fed dipole: ~1.5 dB (~70 W radiated)

- ~1.5 - 2.5 dB advantage to dipole
- Multiband advantage to EFHW

BOTTOM LINE

These kind of losses are normal, not mistakes

Question	Winner
Raw efficiency	Center-fed dipole
RX SNR	Center-fed dipole
Predictable performance	Center-fed dipole
Convenience / space	EFHW

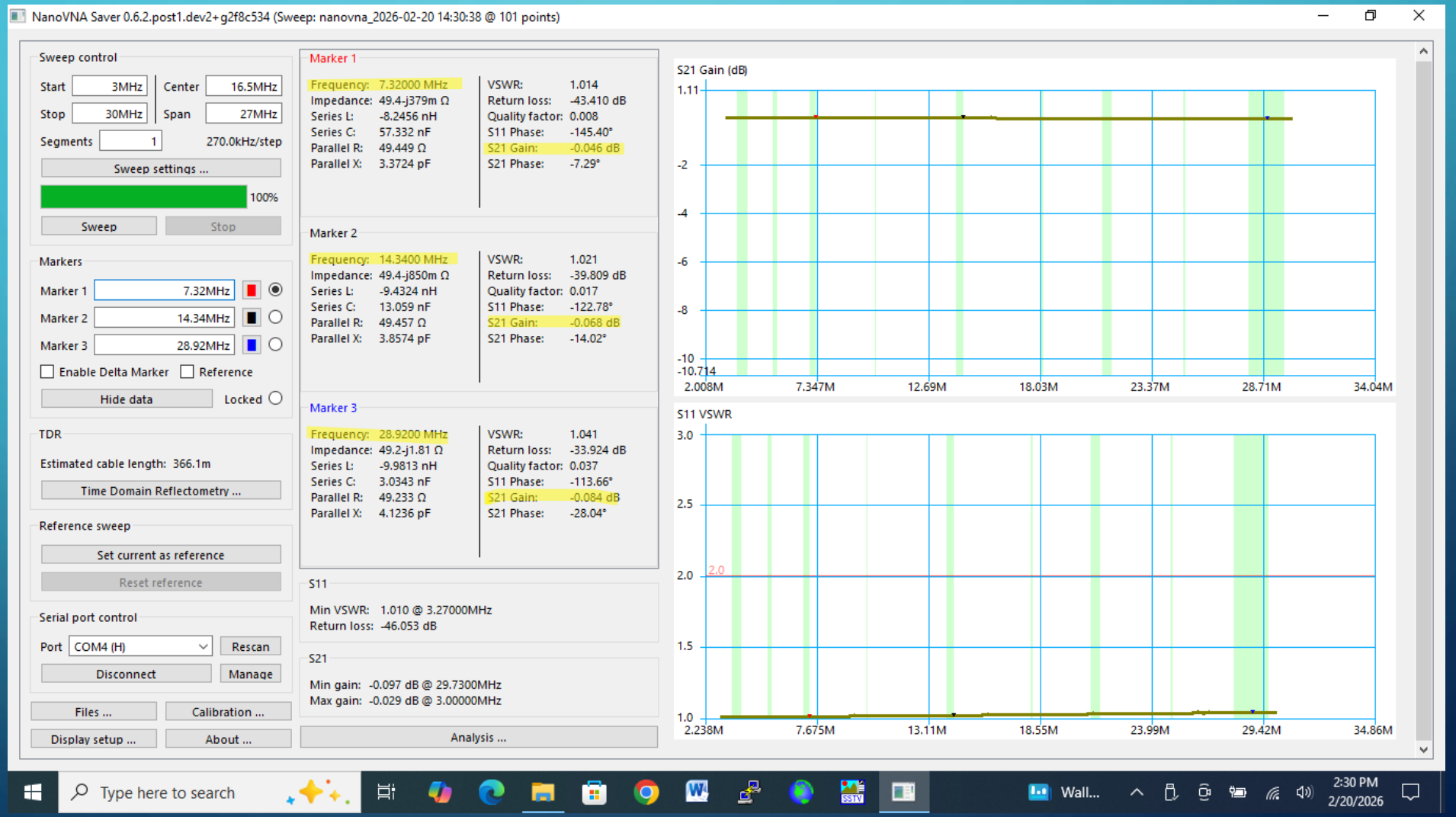
EFHW trades ~2 dB efficiency for convenience

Improvements should focus on efficiency:

- Coax Selection
- Antenna choice

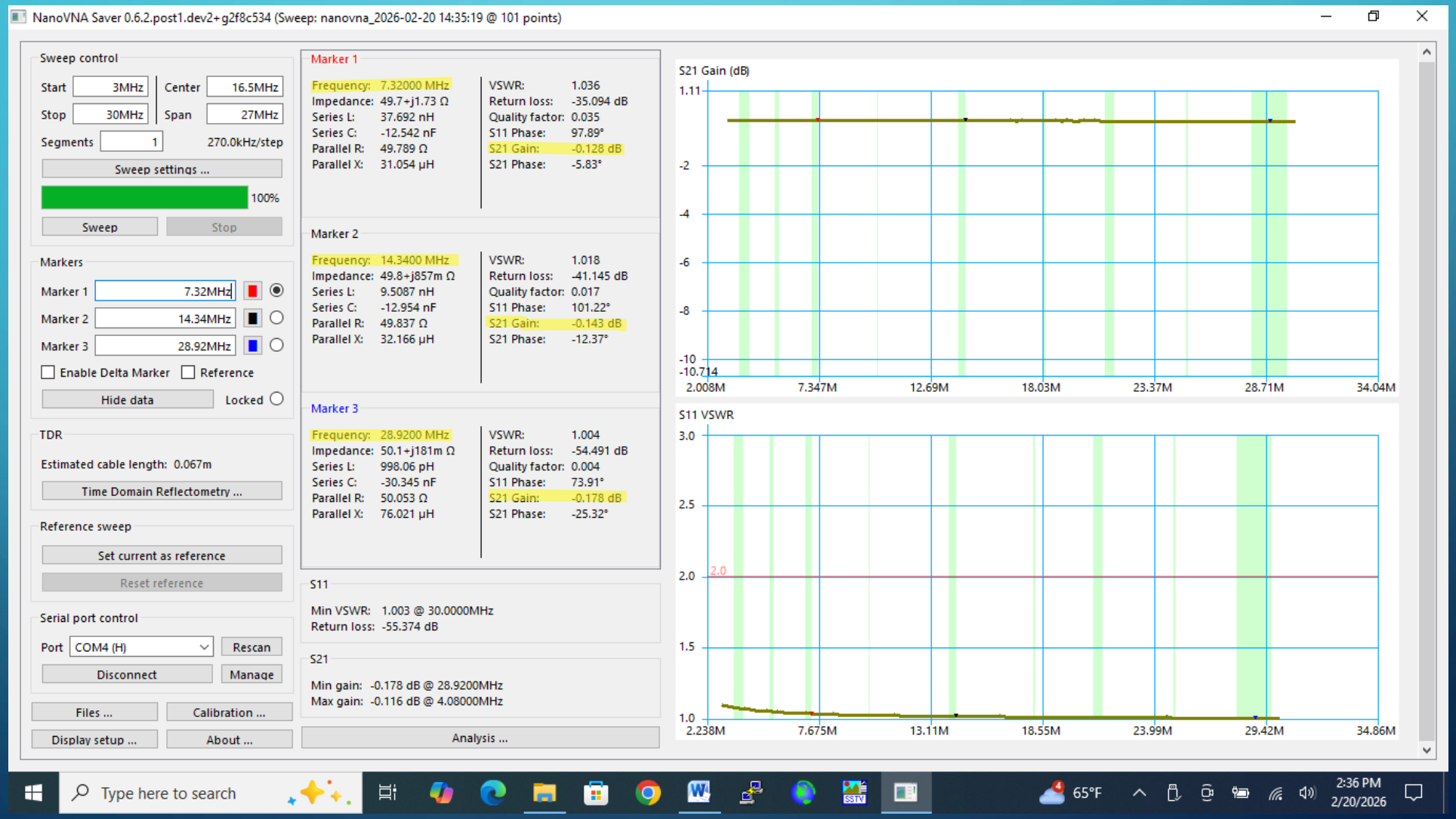
SAMPLE COMPONENT NANOVNA MEASUREMENTS

Manual Antenna Switch Insertion Loss



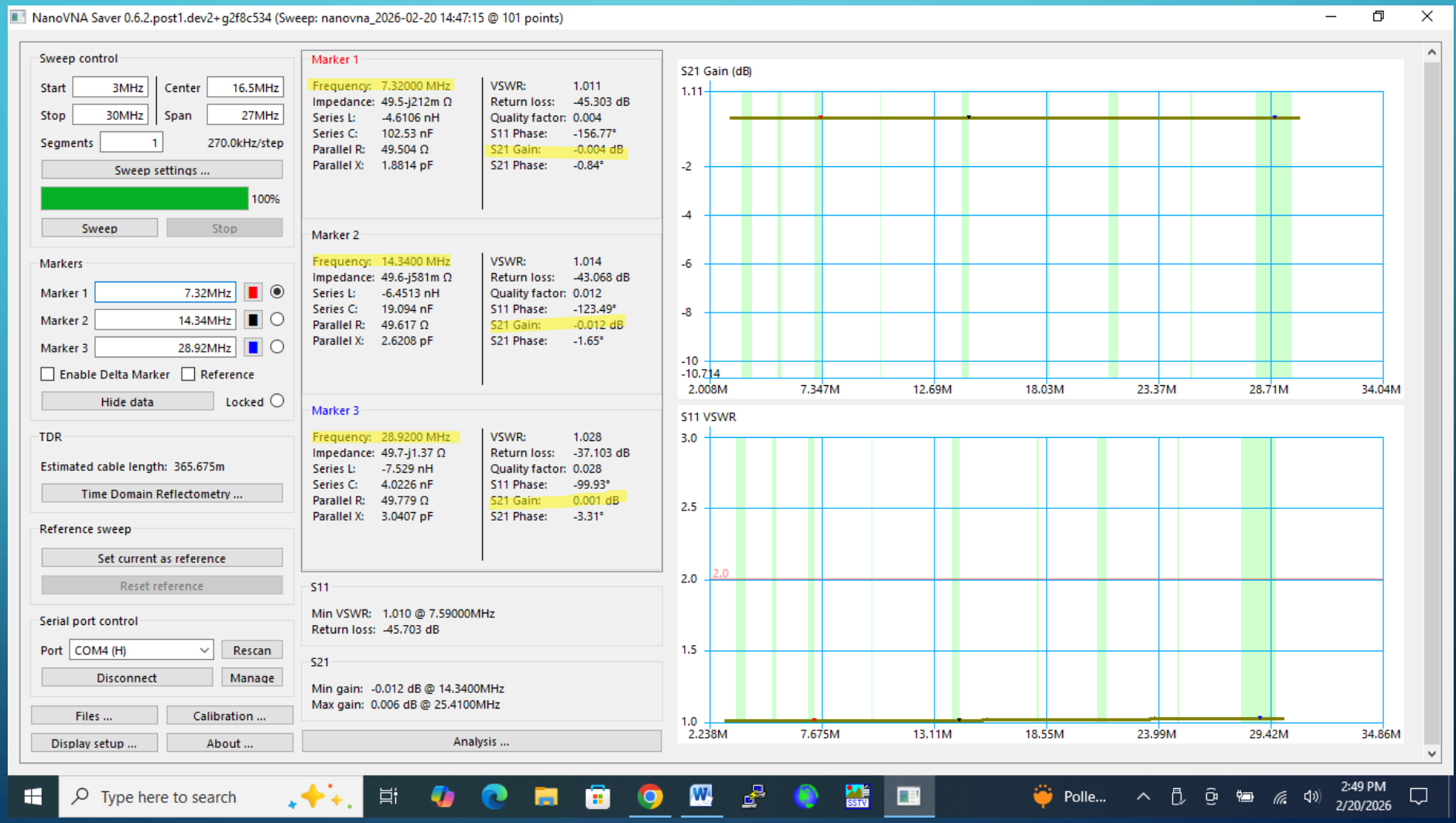
SAMPLE COMPONENT NANOVNA MEASUREMENTS

SWR Meter Insertion Loss



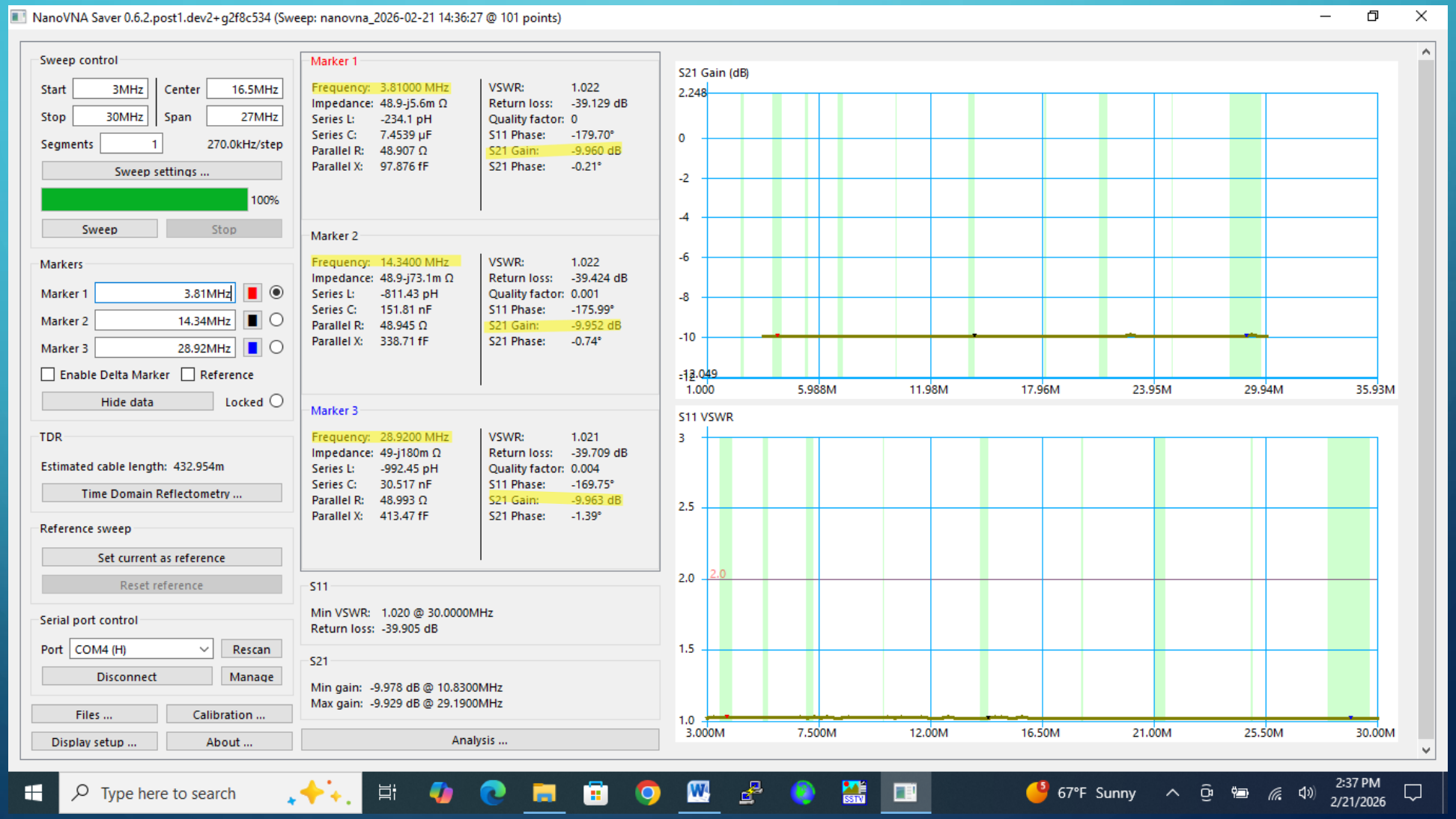
SAMPLE COMPONENT NANOVNA MEASUREMENTS

SO-239 Insertion Loss



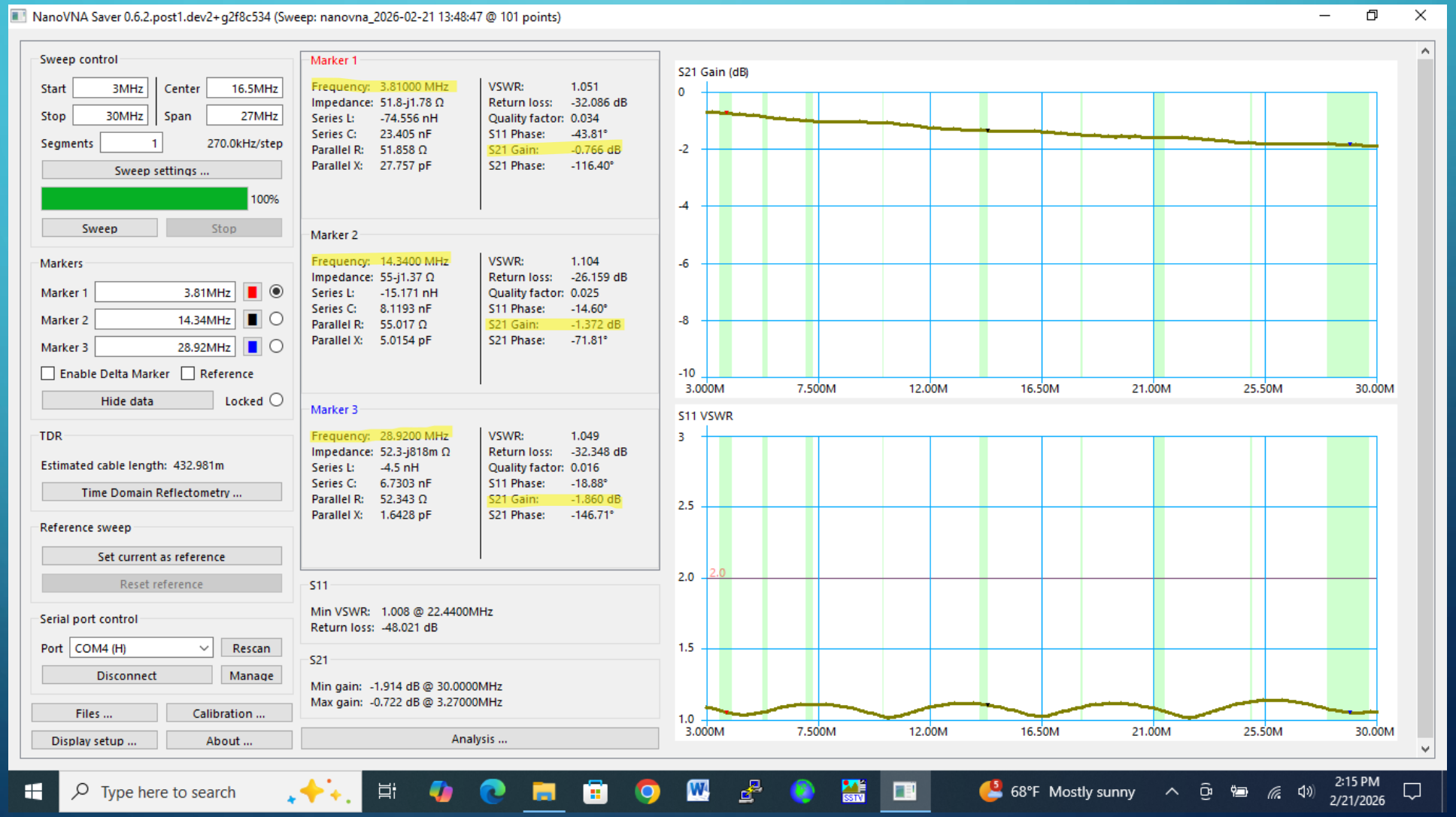
SAMPLE COMPONENT NANOVNA MEASUREMENTS

10dB Attenuator Insertion Loss



SAMPLE COMPONENT NANOVNA MEASUREMENTS

RG-58 Insertion Loss (53.5.ft)



SAMPLE COMPONENT NANOVNA MEASUREMENTS

RG-8X Insertion Loss (100 ft)