Standing Wave Ratio - SWR
What it is…. What it isn't.

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Tech Net #15 2/5/25

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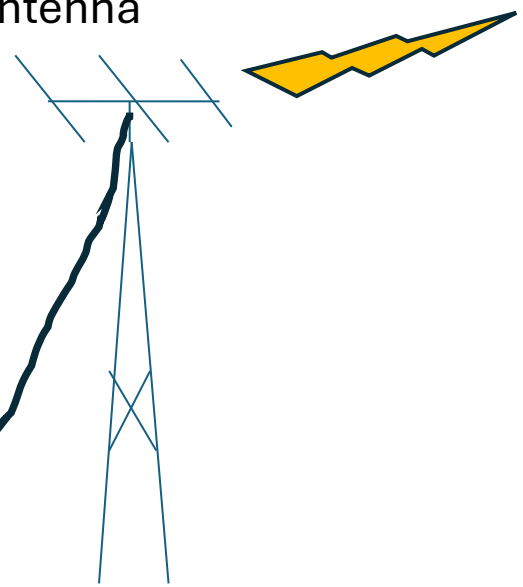
"Your ham ticket is a license to learn." – Bill #1

A worthy goal:
Maximum efficiency in making radio waves

- We want all the power from our transmitter to transfer to our antenna and radiate into “free space” to be received in galaxies far far away.
- Efficiency of our antenna system as close to 100% as possible. Minimum lost power.

“free space”

Antenna

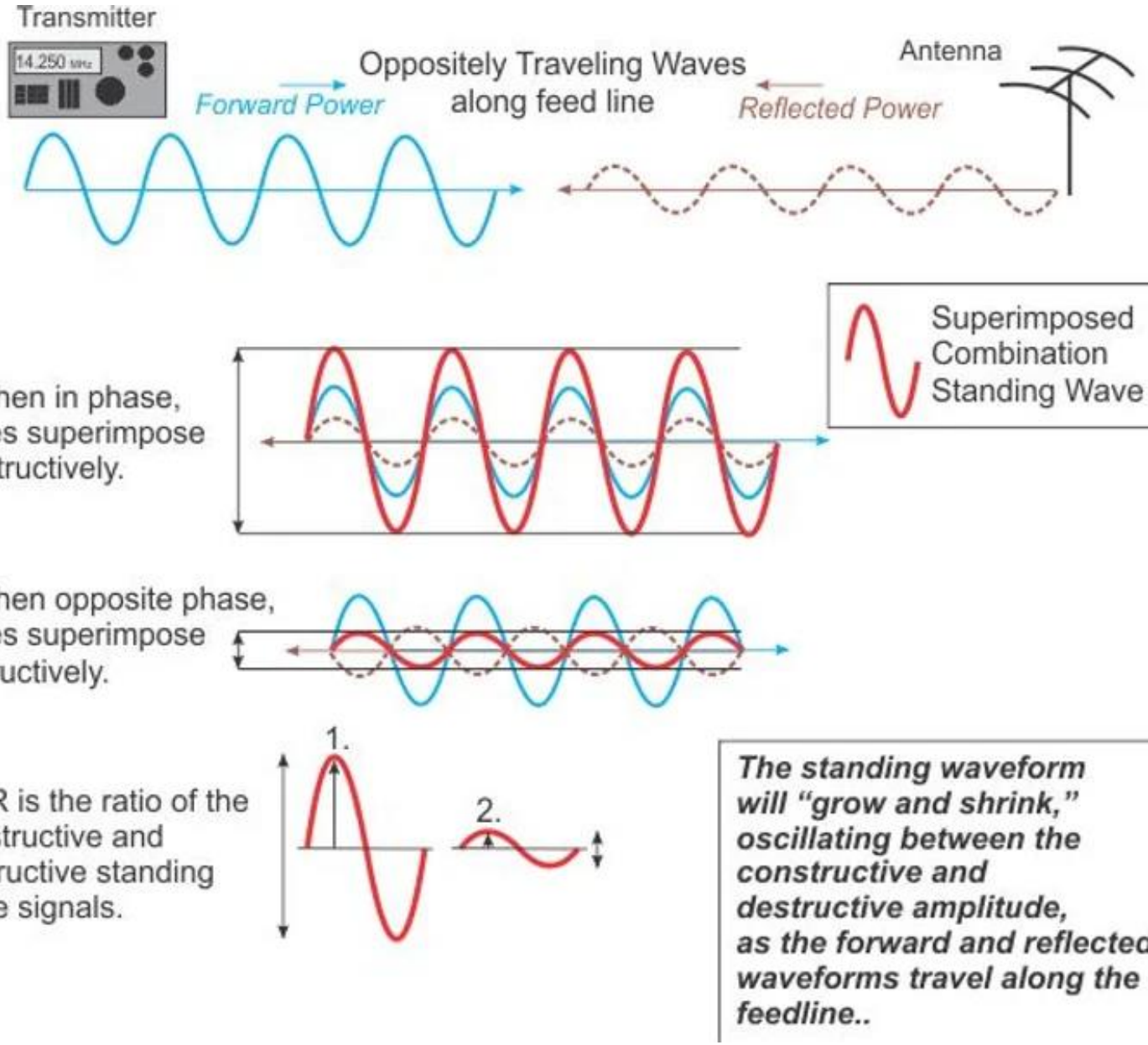


Transceiver

Kelly, AE5II, chatting with aliens

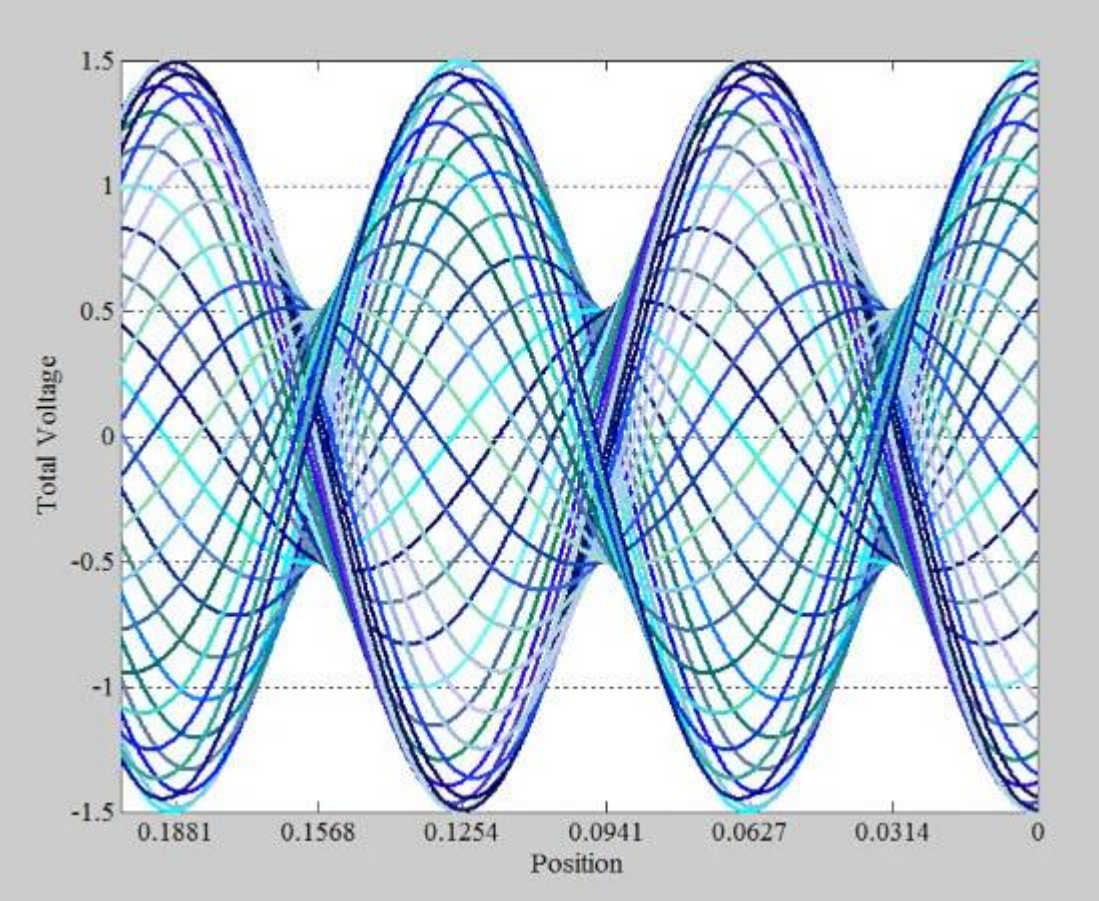
Coax feedline

- We discuss usefulness (or not) of SWR to achieve this goal



https://www.hamradioschool.com/post/swr-perfect-match-t7c04

RF voltage waveforms with 3:1 SWR



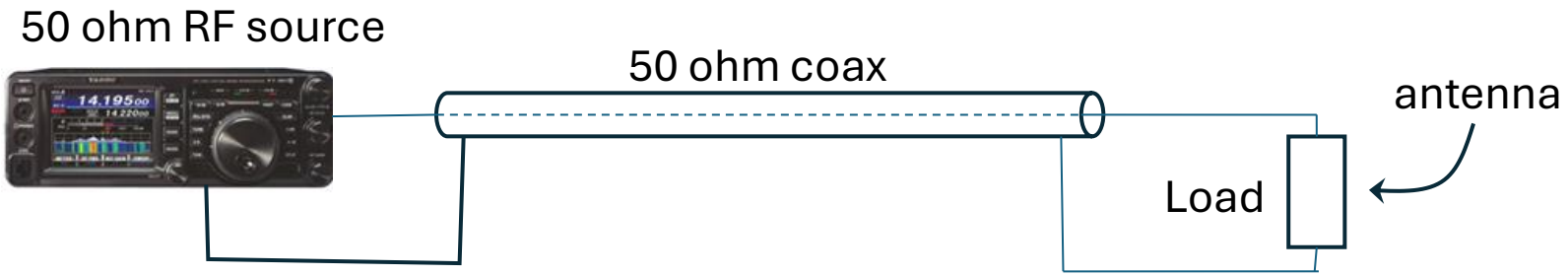
$$VSWR = \frac{V_{max}}{V_{min}} = \frac{1.5}{0.5} = 3$$

https://www.allaboutcircuits.com/technical-articles/radio-frequency-design-basics-voltage-standing-wave-ratio-return-loss-and-mismatch-loss/

What is SWR?... really

Psst...good to know this stuff for your general or extra class license exam

- *Standing waves* occur in the coax when there is an "impedance* mismatch" between source, coax and antenna.



- Getting near to 1:1 SWR is *obsessively pursued* by us hams!
- Widely considered the ultimate good
- 50 ohm resistive load will give 1:1 SWR – *all power into the antenna*
- *A* dipole antenna is typically 72 ohms → SWR 1.44:1
- *A* vertical antenna is typically 36 ohms → SWR 1.38:1
- At any frequency, a dummy load is typically 50 ohms → SWR 1:1

* Impedance explained in appendix

Questions about: What is SWR?

AI5EG

History

- Prior to the WWII, most hams used *ladder line* to feed antennas. Some still do.
  - Ladder line has *very* low loss. Mismatch & SWR was not a big concern.
  - Unwieldy compared to coax
- SWR indicators appeared after WWII with the invention and prevalence of war surplus coax feedline for amateur use.
- Today there are many tools to measure SWR
  - SWR meter in you rig
  - Stand alone SWR meters
  - Rig Expert
  - Nano NVA
  - etc

Ladder line

SWR Misconceptions

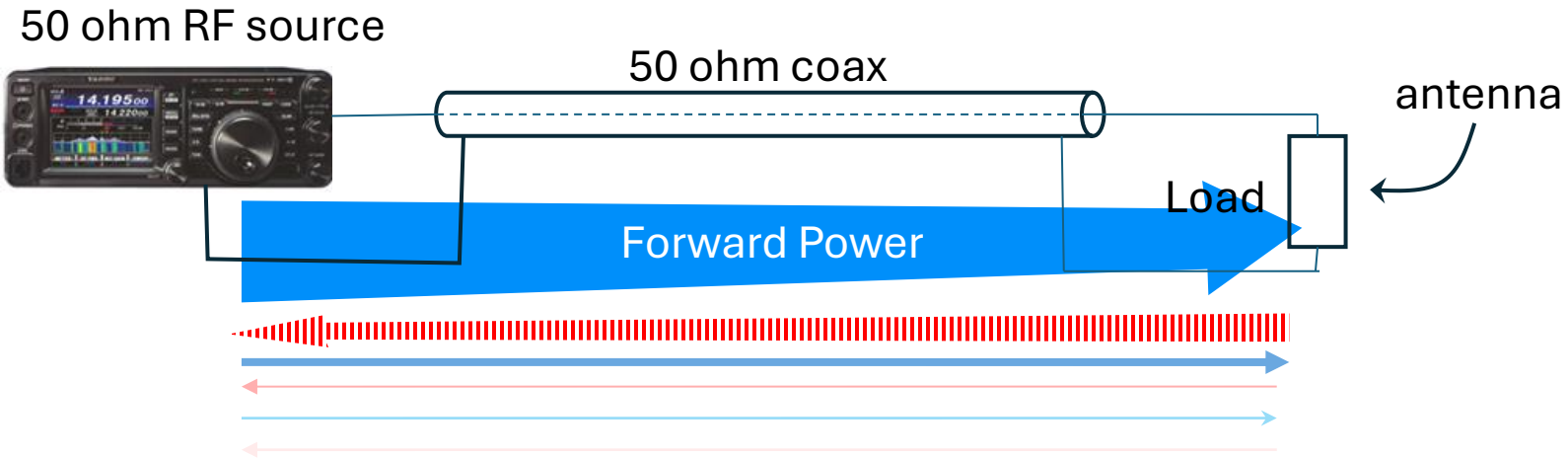
- “I’m not getting out because my SWR is 2.5 to 1”
- “There’s too much power coming back and not enough getting into the antenna”
- “I have 2:1 SWR. Only half of my power is getting out my antenna!”
- “Subtracting reflected power from transmitted power to determine usable power to the antenna”
- “If I feed the coax with that much SWR, the reflected power flowing back into my transceiver will burn it up”*
- “I don’t want my coax to radiate”
- “An antenna SWR of 1.1:1 will work better than an antenna with 2.5:1 SWR”

To measure and compare antenna system performance, *SWR is not the answer*.

Credit: Reflections III – M. Walter Maxwell W2DU

Well, what is SWR all about then? When SWR is higher than 1:1….

- Some power is reflected from the antenna connection back toward to your transmitter
- then *re-reflected back* from transmitter toward the antenna.
- *The <u>only</u> power that is lost in this round trip is the amount dissipated because of coax attenuation (a resistive loss).*



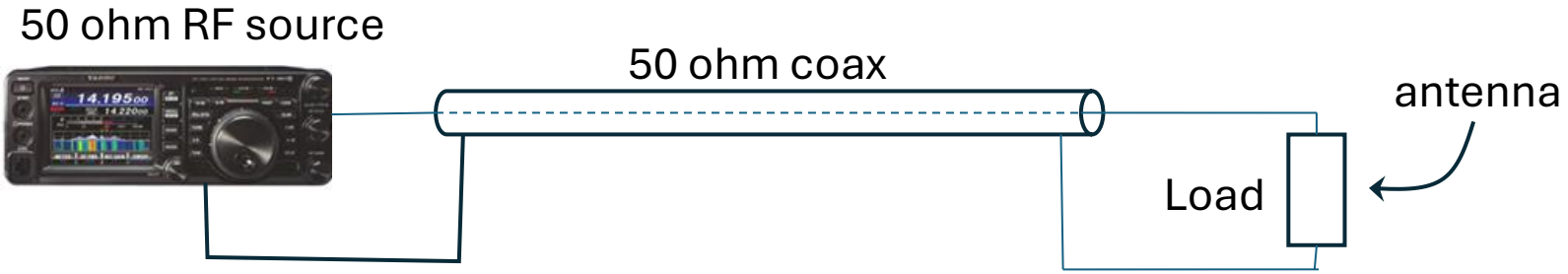
Well, what is SWR all about then? When SWR is higher than 1:1….

- SWR needs to be reasonable.
- High SWR will produce higher voltages on the feedline and your transmitter output stage.
- Modern rigs will reduce drive to protect output transistors from higher voltages that *may* exceed transistor ratings under high SWR conditions.
  - Designed to expect a reasonable amount of power goes into the antenna
  - Reasonable SWR will make your transmitter ‘happy’ so that it doesn’t reduce drive.
  - A tuner at rig will make your transmitter happy but *doesn’t change SWR in the coax* to the antenna, or the losses in the coax.

How does SWR affect power to my antenna?

- Higher SWR will certainly increase loss in your coax due to attenuation (resistive loss) of the reflected waves, but not as much as you might think.
- the difference in *power* transferred through ***any*** coaxial line with an SWR of 2:1 compared to having a perfectly matched 1:1 termination is *imperceptible**.

  * At 2:1 vs 1:1 SWR, the additional loss due to reflected power is *less than human ears can distinguish (~1dB)*.



* decibel, dB, further explained in appendix

Final Thoughts

- SWR need to be reasonable
- SWR measures the *impedance matching* of radio, coax and antenna.
- To measure and compare antenna system performance, comparing SWR is not the answer.
- Low SWR is a good thing, but in most cases efforts to obtain low SWR of 1.1, 1.2 or even 1.5:1 we go far past the diminishing return point for efficient power transfer.
- Low SWR doesn't mean your antenna is an efficient radiator
- Coax is the most important part of your antenna system
- Don't cheap out on coax (or connectors)

* Impedance explained in appendix

End of on-air portion
Questions? Discussions…

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How does SWR affect power to my antenna? Examples .... (assuming *quality* coax.... Amazon? ...not so much)

*100ft RG8x coax: Power losses for **2:1 SWR** measured at the antenna**

Frequency	RG8x SWR 1:1 Coax loss	Additional loss at 2:1 SWR*	Total loss at 2:1 SWR*	SWR reading at rig
5 Mhz	0.65 dB	0.13 dB	0.77 dB	1.8:1
30 Mhz	1.5 dB	0.22 dB	1.7 dB	1.6:1
150 Mhz	3.8 dB	0.39 dB	4.2 dB	1.3:1
450 MhZ	8.6 dB	0.50 dB	9.1 dB	1.1:1

- Added loss due to 2:1 SWR is below difference humans can detect.
- Note: Data table is for 100ft of RG8x – good HF coax
  - Loss is proportional to length.
  - Keep feedlines short if possible
- For VHF & UHF: RG8x not suitable for LONG runs
  - Short runs like in a mobile setup or antenna near the shack should be fine.
  - Use better coax for longer runs at VHF & UHF
- Ironically, higher loss in coax makes SWR at the rig look better.

Reflections III – M. Walter Maxwell W2DU
Understanding SWR by example - K5DVW – ARRL publication
DX Engineering coax selector chart

100 ft of RG58 – cheap, but ??

Frequency	RG58 SWR 1:1 Coax loss	Additional loss at 2:1 SWR*	Total loss at 2:1 SWR*	Power to the antenna
5 Mhz	1.5 dB	0.25 dB	1.8 dB	66%
30 Mhz	2.8 dB	0.33 dB	3.1 dB	49%
150 Mhz	6.2 dB	0.43 dB	6.6 dB	**21%**
450 MhZ	10.6 dB	0.50 dB	11.1 dB	**8%**

100 ft of LMR400 example – good stuff

Frequency	LMR400 SWR 1:1 Coax loss	Additional loss at 2:1 SWR*	Total loss at 2:1 SWR*	SWR reading at rig
5 Mhz	0.2 dB	< 0.1 dB	.2 dB	~ 2:1
30 Mhz	0.7 dB	0.12 dB	.8 dB	~ 1.9:1
150 Mhz	1.5 dB	0.25 dB	1.8 dB	1.7: 1
450 MhZ	2.7 dB	0.32 dB	3.0 dB	1.5:1

* SWR measured at the antenna

SWR and coax attenuation

- Hams operate over a band of frequencies.
  - Reasonable SWR *to the transceiver*, with a tuner if needed.
  - High quality low-loss coax at the frequency bands used
  - High quality coax connectors.
- Lowest possible SWR at the antenna, is a worthy goal for
  - Fixed frequency use i.e. repeaters
  - Narrow ham bands like 30m: 10.100-10.150 Mhz
- At VHF and more so at UHF feedline losses become critical.
  - Good match at the antenna end and super low loss coax
  - Hardline for repeaters or antennas up tall towers
  - Short runs and/or high-performance low loss coax for home stations
  - Short runs for mobile stations.

References and further information

- Understanding SWR by Example K5DVW (ARRL publication)
  "If you only read one article about SWR, I recommend this one" – AI5EG
  https://www.arrl.org/files/file/Technology/tis/info/pdf/q1106037.pdf
- The Truth about SWR: Debunking the Myths and Misunderstandings – *by DXengineering -- easy to follow video*
  https://youtu.be/L1_NLEpsW90?si=BQplQ5W90Ue6muxt
- Ham Radio School
  https://www.hamradioschool.com/post/swr-perfect-match-t7c04
- *Good SWR animations, a little more theory*
  https://youtu.be/BSa051lWB_c?si=SwrP9ibhd-AeZ8qi
- ARRL Antenna Handbook Chapter 23.1
- Reflections III – Chapter 1: Too Low an SWR Can Kill You
  http://www.w4wb.com/Reflections_III.pdf
- DX Engineering Coax Reference Chart
  https://static.dxengineering.com/global/images/chartsguides/d/dxe-11u_vq.pdf?

Food for deeper thought.....
Why some old timers like ladder line?
A ladder line story as told by AI5EG

Data taken from "Understanding SWR by Example K5DVW – ARRL publication"

- Your wise but elderly Elmer uses 300ft of 450ohm ladder line to feed his 10meter antenna that has an impedance of 4500 ohms
- A 4500/450 = 10:1 SWR on the line! Yikes!
- 300ft of 450ohm ladder line has a line loss of 0.5dB
- At 10:1, the added line loss due to the mis-match = 0.9dB
- Total loss = 1.4dB – not bad!
- Tossed a balanced line tuner on his radio and worked some DX
- *You* feed same antenna with only *40 ft of very high-quality 50ohm coax* (0.25db loss), using a tuner to get 1:1 at the radio.
  Total mismatch loss = 12dB = only 6% of your power is radiated.
  - Your Elmer smiles & advises you to put a matching network at the antenna end.
  - You ask, "What's a matching network?"

Some terms… the jargon

Impedance = resistance + reactance

- All measured in ohms. (The math is literally complex: real and imaginary #s)
- *Only resistance* can dissipate power. Value is constant with frequency.
- Pure *reactance*, (ideal inductors & capacitors), dissipate no power, only *store energy* temporarily. Value changes with frequency.

decibel (dB) – a logarithmic scale

dB is used in ham radio to compare/describe signal & power levels.
+1dB = usually too subtle increase for human ear to detect
+3dB = 2x power = ½ S unit
+6db = 4x power = 1 S unit in received signal strength
+10db = ten times power +20db = hundred times power
dBi = in antennas, is dB gain over theoretical isotropic antenna
dBd = power gain relative to a dipole antenna
dBm = power relative to 1 mW of power
The math: dB = 10 times the common logarithm of the power ratio