

I Can Hear Traffic on the Repeater but Why Can't I Hit the Repeater with My HT?

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ARRL The national association for
AMATEUR RADIO

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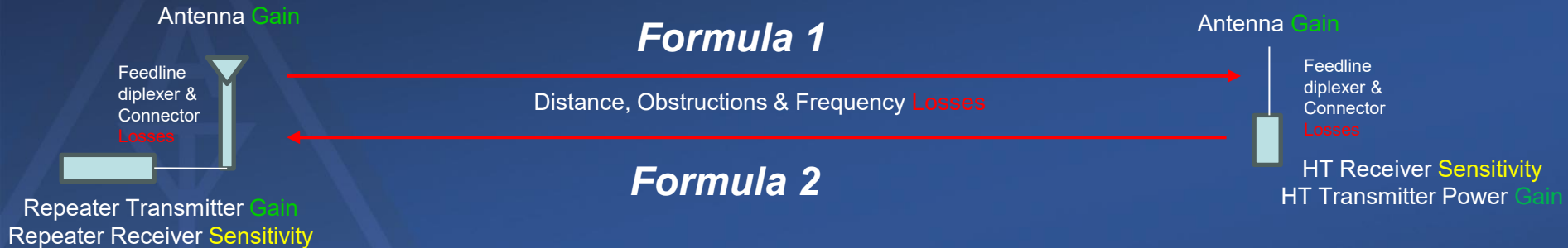
Link Budget

- Ham radio operators often complain they can't access their local repeater with their HT. Why?
- We'll explore the concept of Link Budgets to help answer that question.
- Let's step through what the components of a Link Budget are first.

Link Budget

- A radio **Link Budget** is a systematic accounting of all gains and losses from the transmitter, through the medium (radio spectrum), to the receiver.
- There is a **Link Budget** from the Repeater to the HT and a **Link Budget** from HT to the Repeater. (We'll look at a diagram next slide)
- To answer the question why I can't "HIT" the repeater from my HT is because the **Link Budget** is out of balance.

Simplified Link Budget Diagram



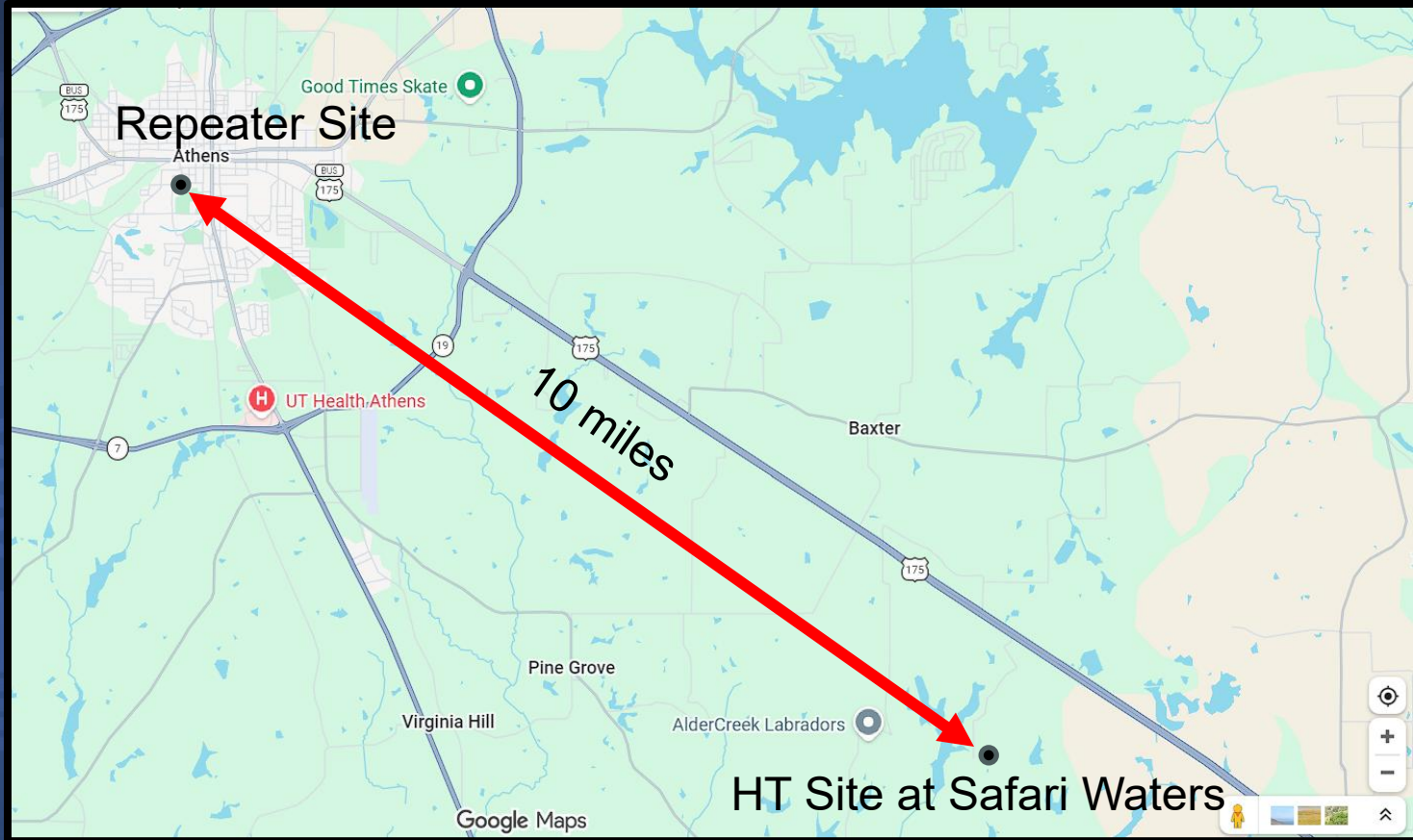
Formula 1 – From the Repeater to the HT

Power at the HT receiver's input (dBm) = Power of the Repeater transmitter (dBm) – Repeater Feed Line Loss (dBm) + Repeater Transmitter Antenna Gain(dBi) – Free Space Loss (dB) – Miscellaneous Losses (dB) + HT Antenna Gain (dBi) – HT Feed Line Loss

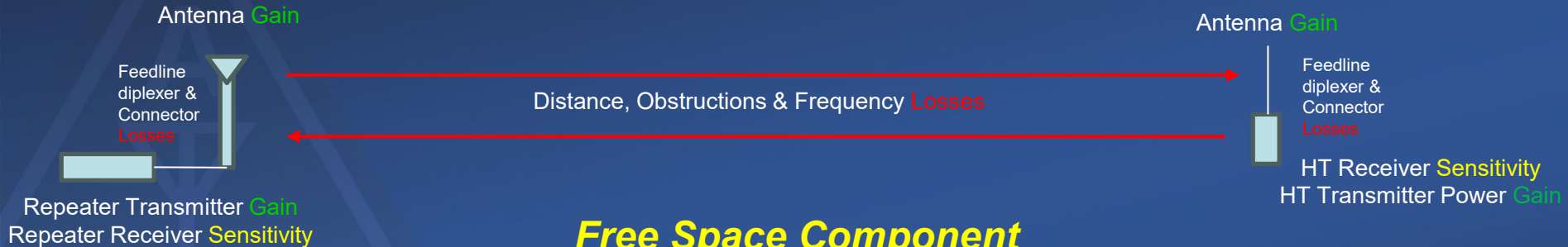
This is the critical link → *Formula 2 – From the HT to the Repeater*

Power at the Repeater receiver's input (dBm) = Power of the HT transmitter (dBm) – HT Feed Line Loss (dBm) + HT Transmitter Antenna Gain(dBi) – Free Space Loss (dB) – Miscellaneous Losses(dB) + Repeater Antenna Gain (dBi) – Repeater Feed Line Loss

Link Budget AARC Tackled



Free Space Loss Component



Free Space Component
It is impacted by frequency and distance

Power at the Repeater receiver's input (dBm) = Power of the HT transmitter (dBm) - HT Feed Line Loss (dBm) + HT Transmitter Antenna Gain(dBi) - **Free Space Loss (dB)** - Miscellaneous Losses (dB) + Repeater Antenna Gain (dBi) - Repeater Feed Line Loss

Free Space Formula

Free Space Loss = $20 \log_{10}(d) + 20 \log_{10}(f) + 32.45$

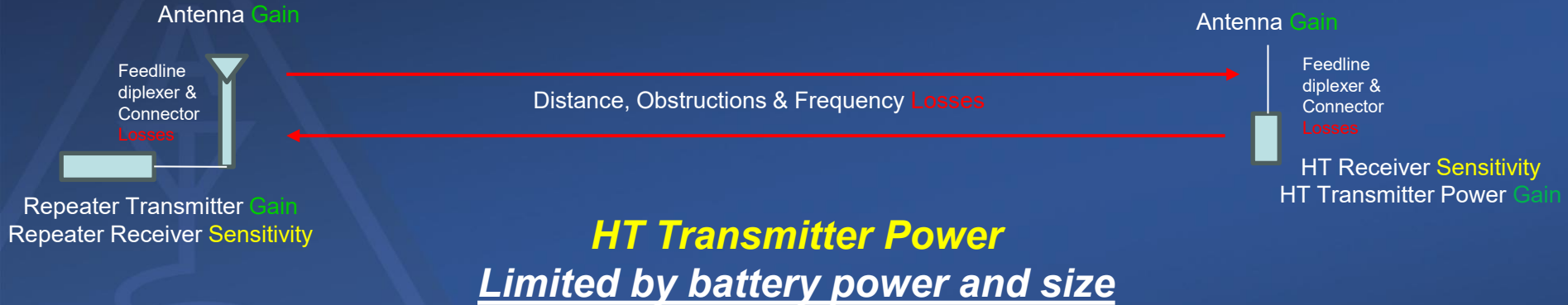
d = distance (km)

f = frequency (MHz)

32.45 is a constant

Using our formula -> 16 km ~
10 miles results in **100 dB** of
Free Space loss at 145 MHz

HT Transmitter Component



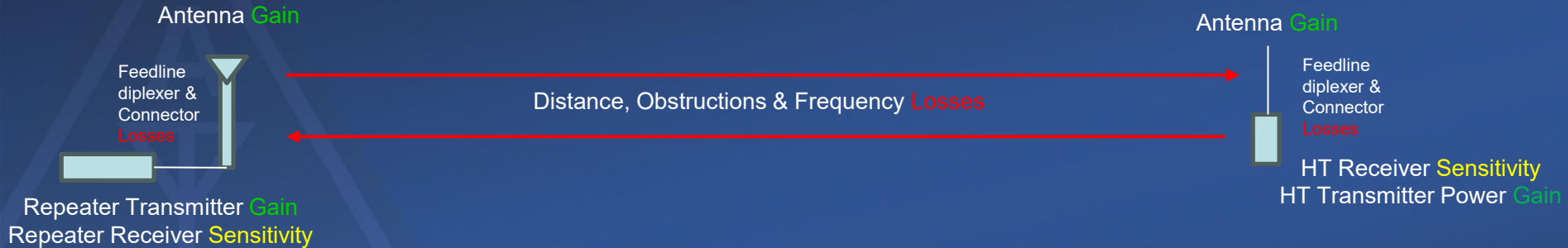
Power at the Repeater receiver's input (dBm) = **Power of the HT transmitter (dBm)** - HT Feed Line Loss (dBm) + HT Transmitter Antenna Gain(dBi) - Free Space Loss (dB) - Miscellaneous Losses(dB) + Repeater Antenna Gain (dBi) - Repeater Feed Line Loss

Watts to dBm Formula

$$\text{dBm} = 10 \log_{10}(\text{Watts} \times 1000)$$

Using our formula ->5 Watts
 is the same as **+37 dBm**

What Losses & Gains Remain



Formula 2 – From the HT to the Repeater

Power at the Repeater receiver's input (dBm) = Power of the HT transmitter (dBm) – HT Feed Line Loss (dBm) + HT Transmitter Antenna Gain(dBi) – Free Space Loss (dB) – Miscellaneous Losses (dB) + Repeater Antenna Gain (dBi) – Repeater Feed Line Loss

What's this!

What Losses & Gains Remain

Formula 2 – From the HT to the Repeater

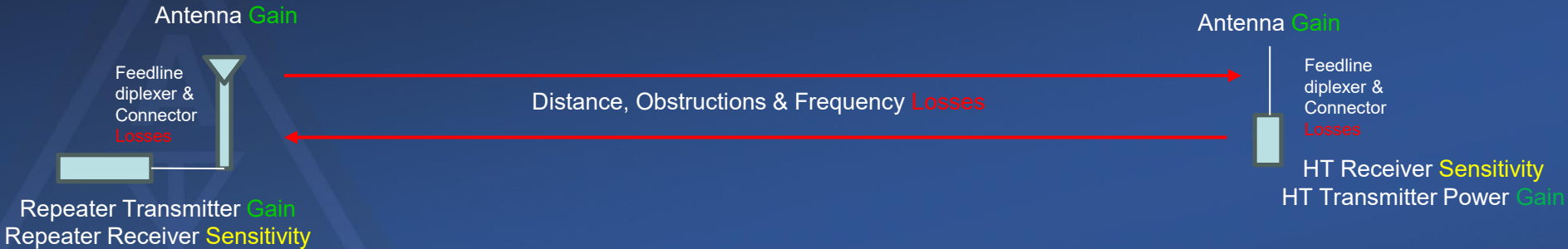
Power at the **Repeater** receiver's input (dBm) = Power of the **HT** transmitter (dBm) – **HT Feed Line Loss** (dBm) + **HT Transmitter Antenna Gain**(dBi) – Free Space Loss (dB) – **Miscellaneous Losses**(dB) + **Repeater Antenna Gain** (dBi) – **Repeater Feed Line Loss**

HT Feed Line Loss (dBm)	1 dBm
HT Transmitter Antenna Gain (dBi)	0 dBm
Repeater Antenna Gain (dBi)	3 dBi
Repeater Feed Line Loss (Helix & Lighting Arrestor) 0.80dB/100' =	2 dB (120 feet)
Miscellaneous Losses (dB)	60 dB

These 5 loss and gain components in the link budget net out to **-60 dB**

Miscellaneous Losses include: Multipath Fading (**20 dB**), Rain (**18 dB**), Shadowing (Foliage) (**20 dB**), Pointing (**1 dB**), Polarization Mismatch (**1 dB**)
= **60 dB**

Let's Run The Numbers



This is the critical link → **Formula 2 – From the HT to the Repeater**

Power at the Repeater receiver's input (dBm) = Power of the HT transmitter (dBm) - HT Feed Line Loss (dBm) + HT Transmitter Antenna Gain(dBi) - Free Space Loss (dB) - Miscellaneous Losses(dB) + Repeater Antenna Gain (dBi) - Repeater Feed Line Loss

Power at the Repeater receiver's input (dBm) = +37 dBm - 100 dB - 60dB = - 123 dBm

What does -123 dBm mean? It's the power level at the repeater's RF receiver that comes from the sum of all the gains and losses from the HT transmitter toward the repeater. NOW WE HAVE TO DETERMINE IF OUR REPEATER'S RECEIVER IS SENSITIVE ENOUGH TO PULL THIS SIGNAL POWER OUT OF THE NOISE!

Determine Repeater's Sensitivity

We start with this:

Power at the **Repeater** receiver's input (dBm) = +37 dBm - 100 dB - 60dB = - 123 dBm

Our repeater has a specification. For the AARC repeater the receive side of the repeater has a sensitivity spec which is:

Minimum Receiver Sensitivity for a Yaseu DR repeater is 0.22 uV @ 50 ohms

We have to convert the receiver sensitivity measured in microvolts to power. To do that we need a couple of formulas: We know that Power = Voltage (E) * Current (I) and we know voltage (E) but not current (I). To get to current (I) we go back to Ohm's Law. $E = I * R$ and solve for I which is equal to E/R and we know E and we know R.

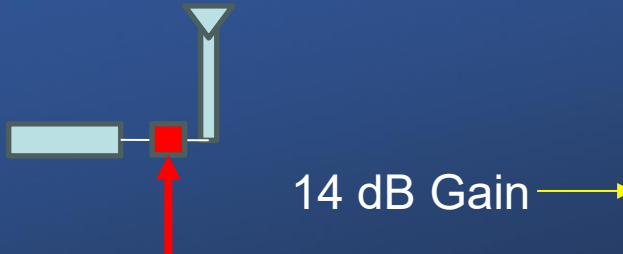
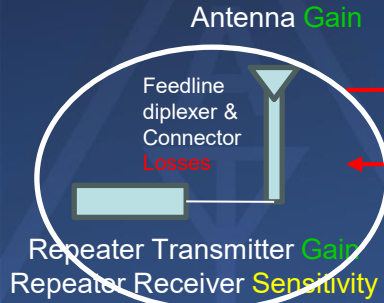
Formula is Power = $E * E/R = E^2/R$ and we have to convert to dBm = -120 dBm (I have a spreadsheet for these calculations)

For reliable communications our radio receiver must have -120 dBm of power present at the antenna connector. (Reliable is defined as the power level at the RF front-end allowing the repeater to discriminate between noise and signal. The received signal is subject to both thermal and external noise.)

Our Link Budget Analysis reveals we DO NOT have any **LINK MARGIN** but rather a **shortfall of 3 dB** ($-123 \text{ dBm} - (-120 \text{ dBm}) = -3 \text{ dBm}$)

How do we fix this?

We were 3 dB short in our HT to REPEATER link budget and the preamp added 14 dB gain in the receiver chain. Now an HT 10 miles away can access the AARC repeater when before it was not possible.



We added a PREAMP between the repeater receive input and the diplexer resulting in a new signal level of $(-123 \text{ dBm} + 14 \text{ dB} = -109 \text{ dBm})$. We now have a **LINK MARGIN** of $(120 - 109) = 11 \text{ dB}$ where before we had none.

Custom Products from Masters Communications

EPGA103+2M

Enclosed VHF Low-Noise High Dynamic Range RF Preamplifier for receive applications and duplex (repeater) service.

\$145.00 built, tested, tuned - any available connector choice - shipping extra.
\$14.50 USPS Priority Insured Shipping in the US.
Shipping on foreign orders are quoted by destination.

Ham & Commercial
135 - 162 MHz.

Includes tuned input filtering for narrower operating frequency range.
Great for repeater service.

Click image for alternate view.

Masters Communications EPGA103+2M Preamp - Standard Features:
These standard features are included in the EPGA103+2M Preamp.

- L/C tuned input circuit to help protect against out of band overload.
- Uses a genuine MiniCircuits PGA103+ amplifier chip.
- Very Low Noise - typically ~ 1.3 dB noise figure.
- -3dB bandwidth - 25 MHz.
- 100% totally shielded aluminum box - properly machined for rugged / stable operation.
- 12VDC operation at moderate current draw (7-15V acceptable - about 60-70 mA typical).
- PGA103+ circuit runs at 3.5 volts - internally regulated (low-noise linear regulation).
- P1dB = +17dBm at the device, +11 dBm at the output connector - because of output attenuator.
- Available with BNC, UHF, or N Female Connectors (or a unique combination of any two -- can eliminate adapters)
- Moderate Gain (held to about 14dB) - Less chance of receiver overload.
- These preamps are NOT available as unassembled project kits - comes ready to install.
- Power connection is made on the outside via DC Feedthru and ground lug (soldering preferred).
- 24" Siamese Black/Red power wire supplied - longer lengths available, small fee applies.
- \$145.00 assembled, tested - with any connector option (BNC, UHF, N - any two).
- Built to order and professionally tuned on a HP 8753ES Vector Network Analyzer.
- Great input match so your diplexer notch tuning is not pulled out of whack.
- Comes with performance graphs showing gain and input return loss (match) on your frequency.

Questions & Comments

A faint, light blue background diagram of an electrical circuit is visible on the left side of the slide. The circuit is enclosed in a diamond-shaped frame. At the top is a diode symbol with the letter 'A' above it. Below the diode is a resistor symbol with the letter 'R' on either side. Below the resistor is an inductor symbol (a coil) with the letter 'L' below it. At the bottom is a battery symbol.