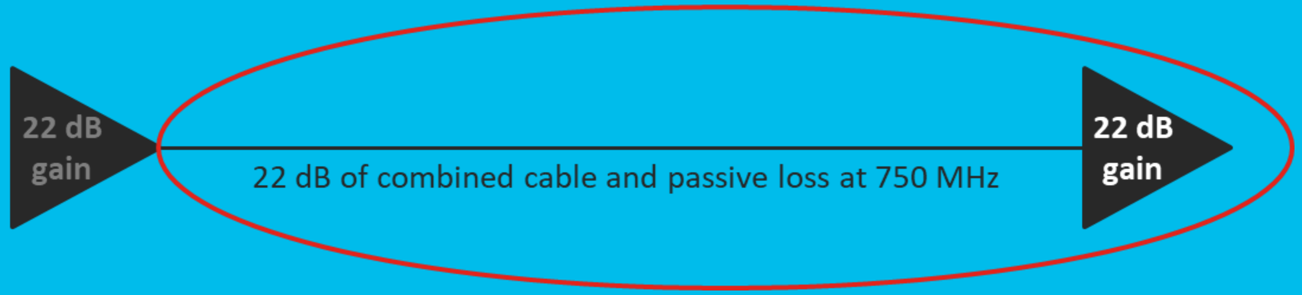
Understanding Unity Gain



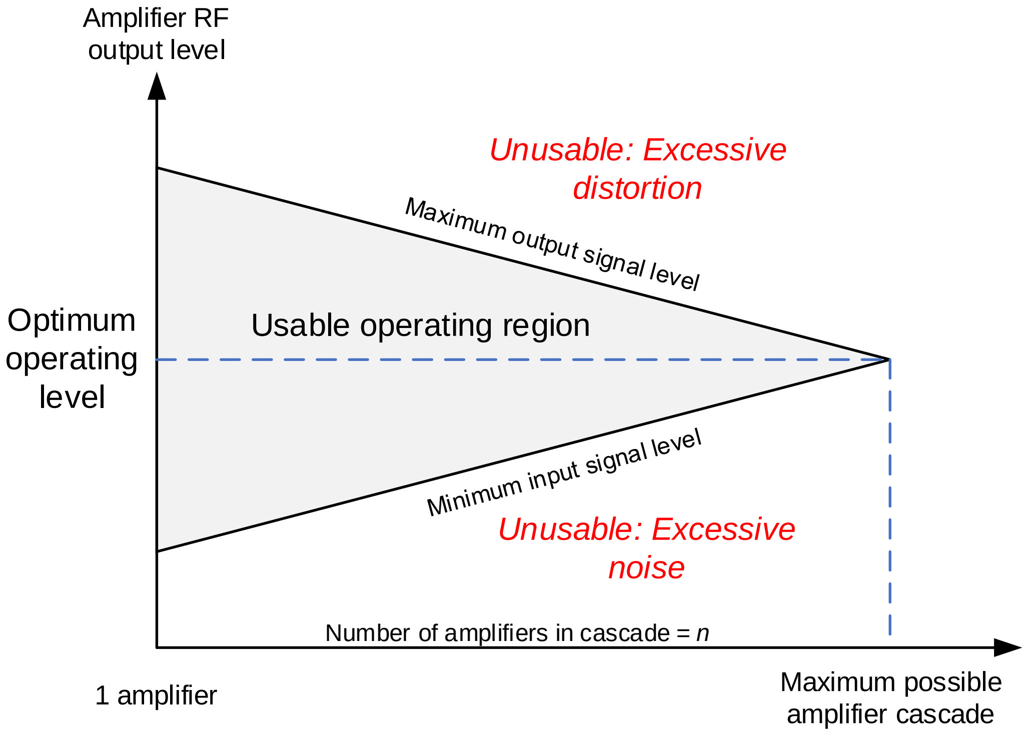
Ron Hranac

What is unity gain?

Cable network performance is a delicate balance between noise and distortion. If the network's radio frequency (RF) levels are too low, the carrier-to-noise ratio (CNR) will degrade, and if RF levels are too high, the carrier-to-distortion ratio will suffer.

What is unity gain?

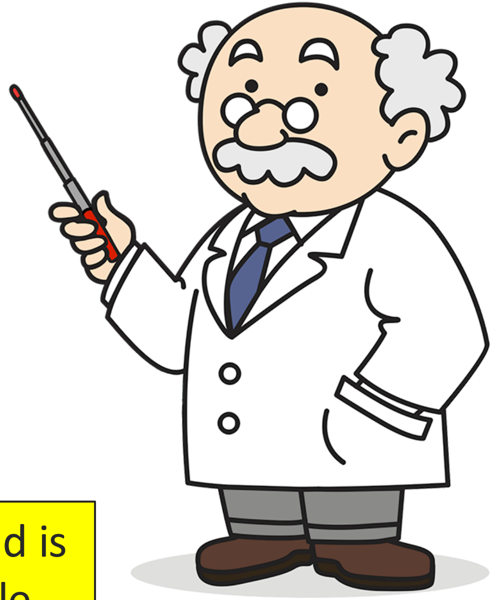
This means the network's operating RF levels must be confined to a moderate window that becomes smaller as the signals pass through more and more active devices.



Graphic source adapted from *Modern Cable Television Technology, 2nd Ed*.

What is unity gain?

Very early in the cable industry's history it was discovered that for optimum performance of cascades of identical amplifiers, the gain of each amplifier in decibels (dB) should be numerically equal to the total loss in dB of the cable and passive devices (*at the highest operating frequency*) immediately upstream from that amplifier.

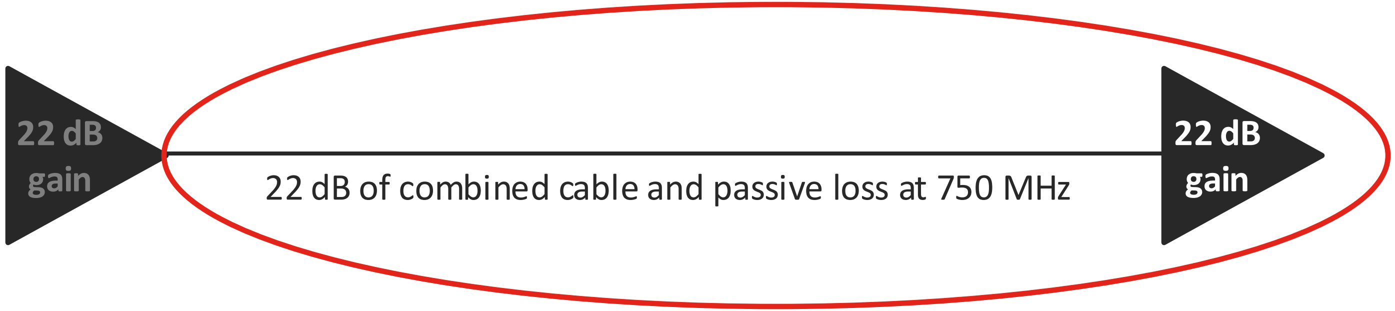


This concept is known as unity gain, and is still a critical parameter in modern cable network design and operation.

What is unity gain?

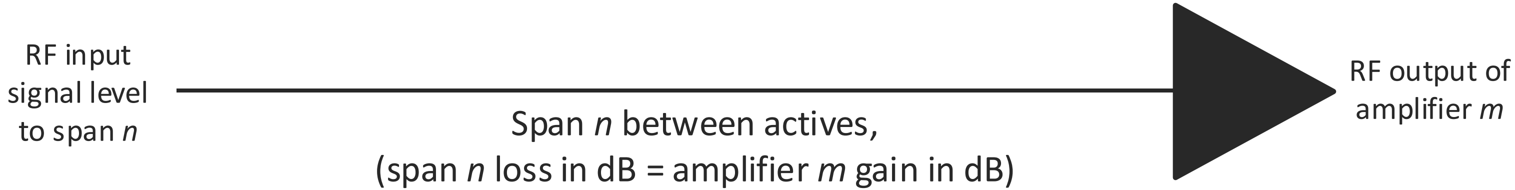
That is, in a properly designed and operating cable network, the loss (at the highest operating frequency) in the coaxial cable and passive devices comprising the span immediately upstream from an amplifier is exactly offset by the gain of the amplifier, resulting in unity or no net gain.

For instance, if a span of cable between two downstream actives has 22 dB of combined cable and passive loss at, say, 750 MHz, and the gain of the amplifier following that span is 22 dB, then **unity gain exists** for that span + amplifier.



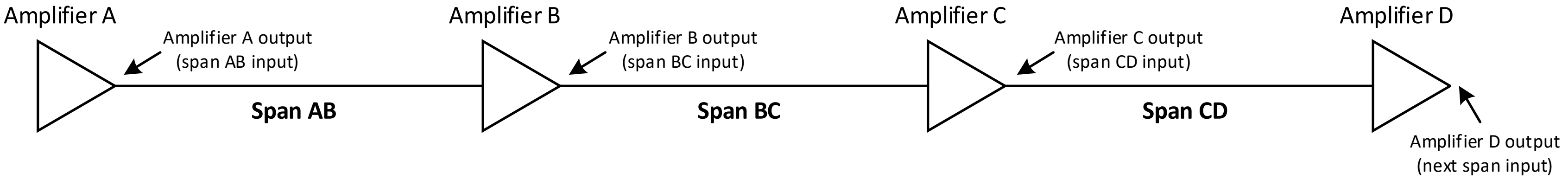
What is unity gain?

When forward path unity gain exists, the input signal level to a given span of cable will equal the output signal level of the amplifier immediately following that span of cable. (*There are occasional exceptions – for instance, the transition from a bridger amplifier to a derated line extender*.)



What is unity gain?

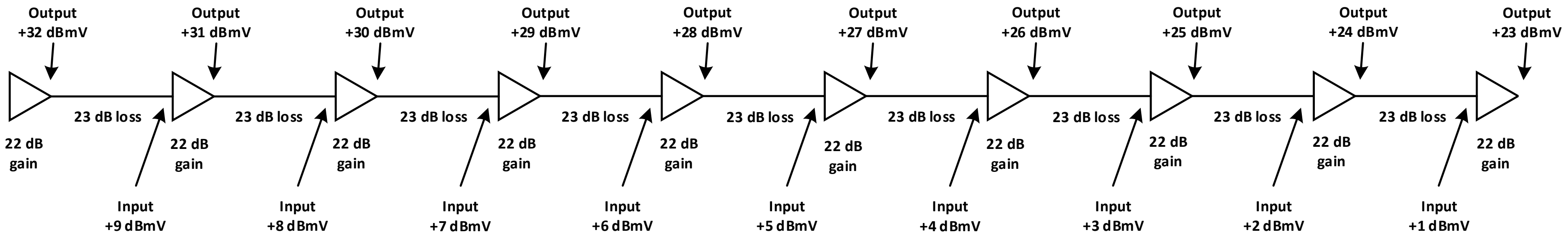
The accompanying graphic shows a cascade of four identical amplifiers. In this example, unity gain exists when the input to span AB equals the output of amplifier B, the input to span BC equals the output of amplifier C, the input to span CD equals the output of amplifier D and so on. This also defines a system's unity gain reference point, something we'll get back to a little later.



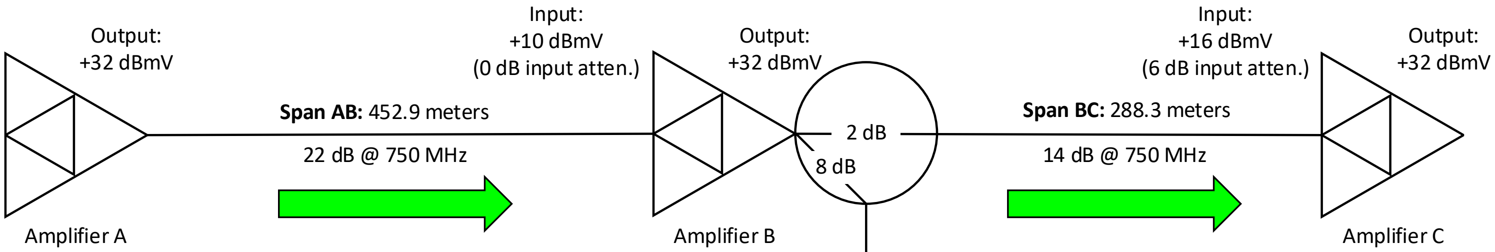
The importance of unity gain

Imagine a cascade of 10 identical amplifiers, each with 22 dB of gain. However, assume the loss between each amplifier is 23 dB.

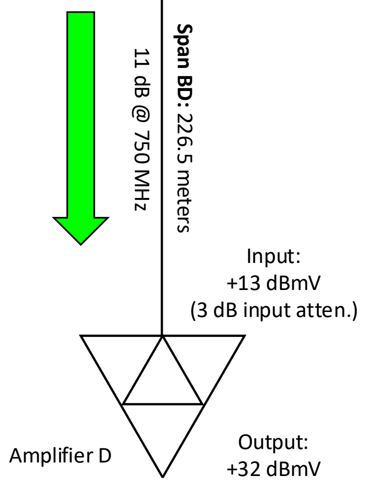
- If the output of the first amplifier is +32 dBmV, then the input to the second amp will be 32 dBmV – 23 dB = +9 dBmV. The second amplifier's output will be 9 dBmV + 22 dB = +31 dBmV.
- The input to the third amplifier will be 31 dBmV – 23 dB = +8 dBmV and its output 8 dBmV + 22 dB = +30 dBmV.
- By the time we get to the tenth amplifier in cascade, the input level will be +1 dBmV and the output +23 dBmV. CNR performance will be much less than ideal in this hypothetical cascade!



Downstream unity gain

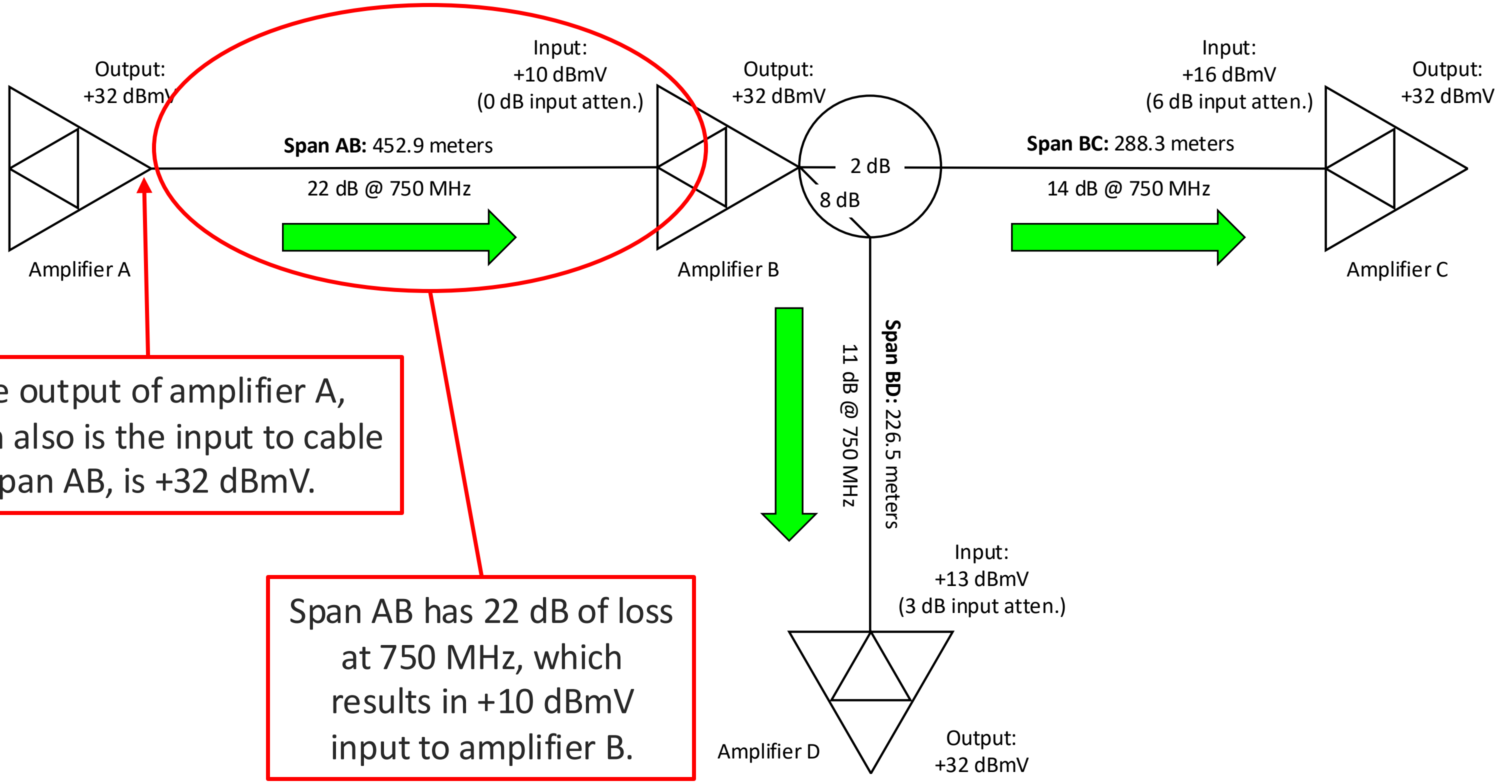


This graphic illustrates an example of forward path unity gain in a hypothetical 750 MHz network. The assumption is a cascade of identical downstream amplifiers, each with 22 dB of gain.



452.9 m ≈ 1486 ft
288.3 m ≈ 946 ft
226.5 m ≈ 743 ft

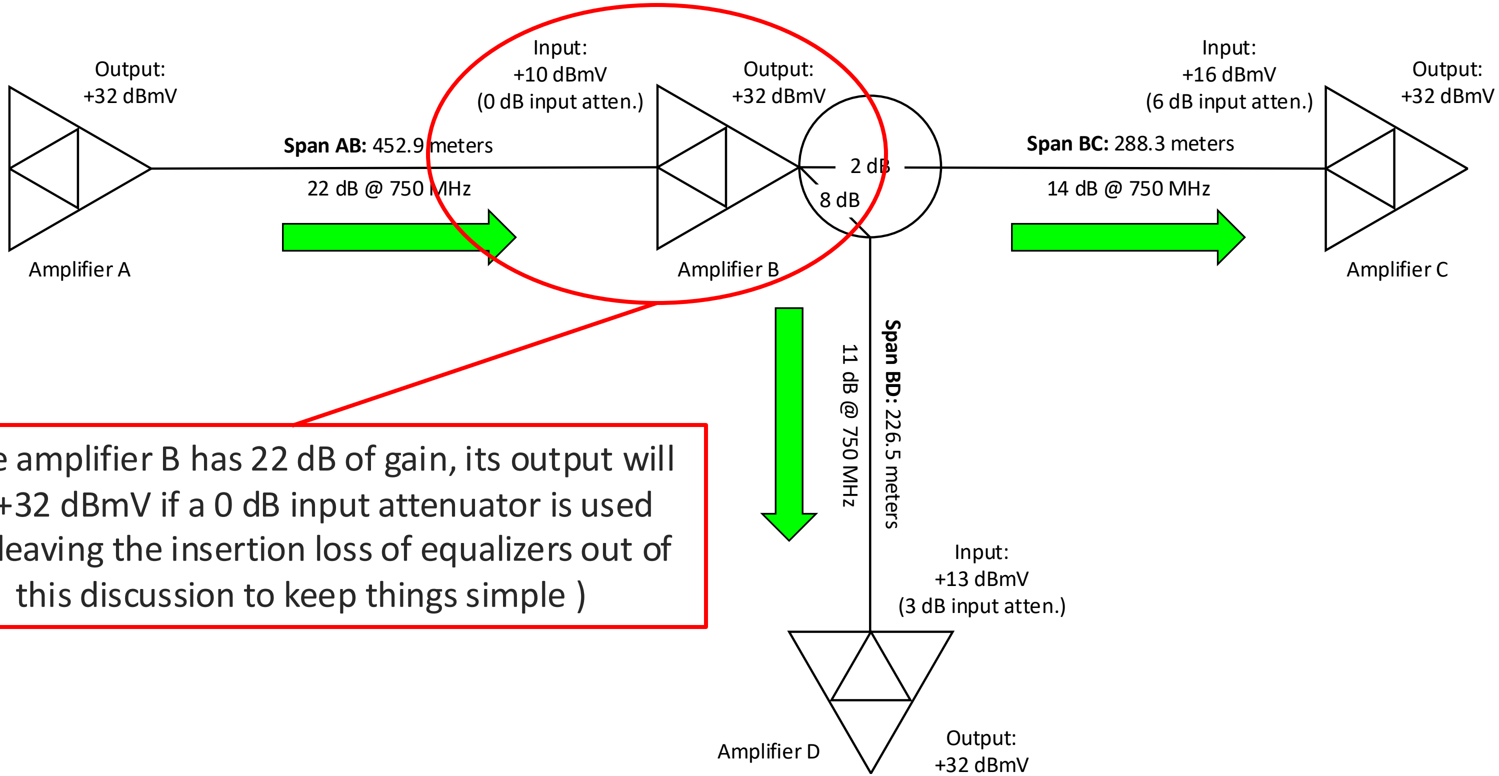
Downstream unity gain



The output of amplifier A, which also is the input to cable span AB, is +32 dBmV.

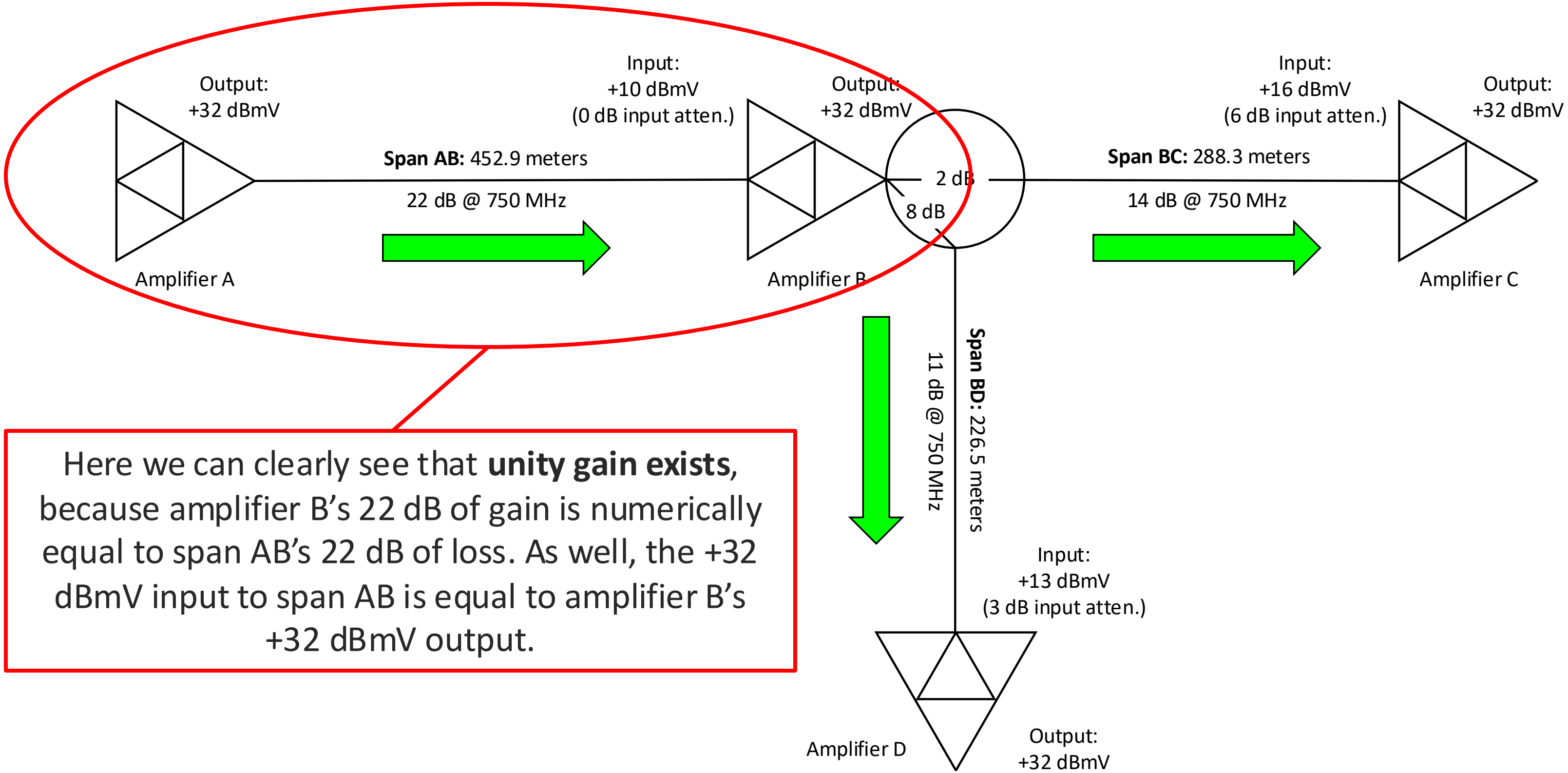
Span AB has 22 dB of loss at 750 MHz, which results in +10 dBmV input to amplifier B.

Downstream unity gain



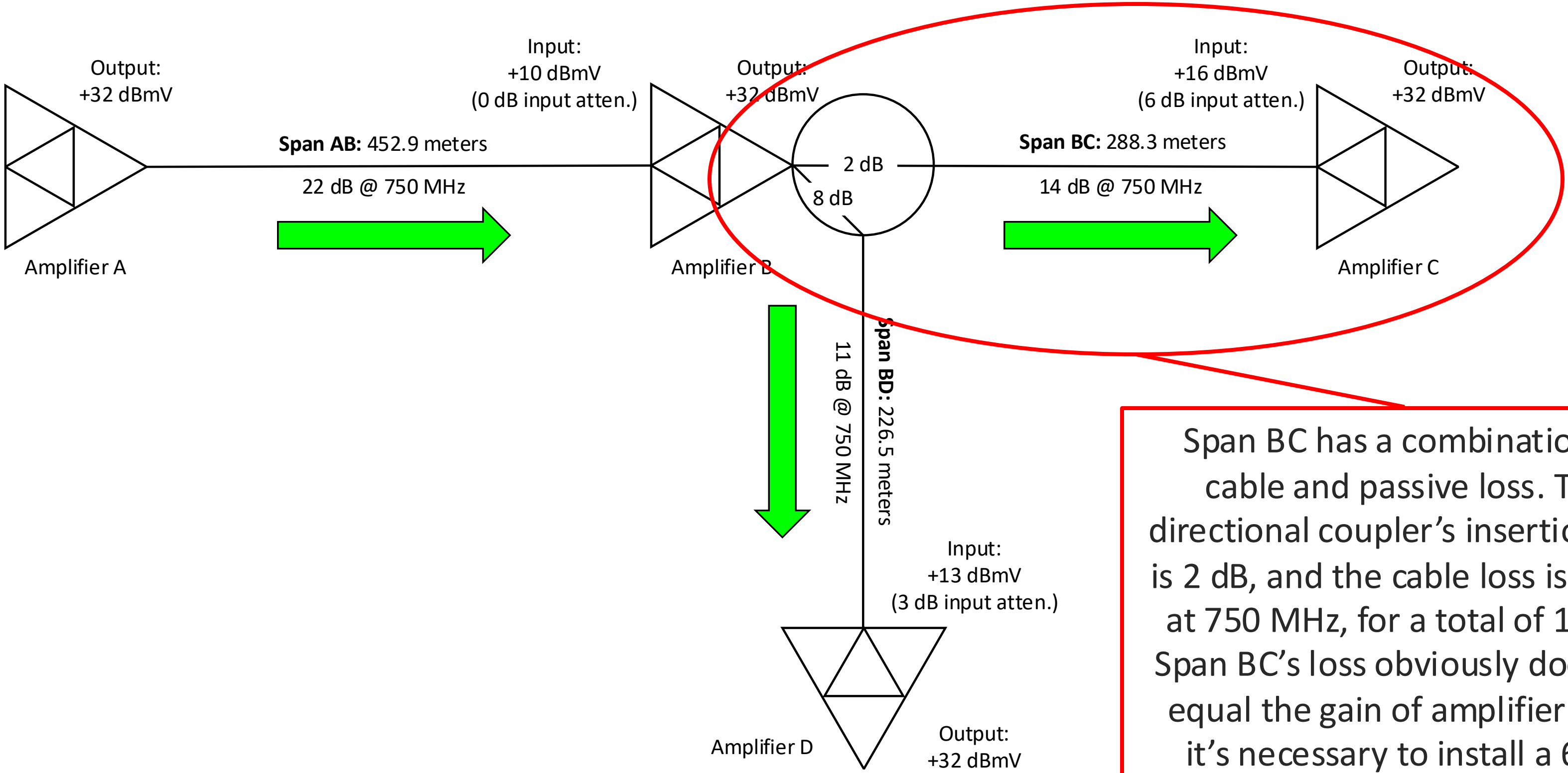
Since amplifier B has 22 dB of gain, its output will be +32 dBmV if a 0 dB input attenuator is used (I'm leaving the insertion loss of equalizers out of this discussion to keep things simple)

Downstream unity gain



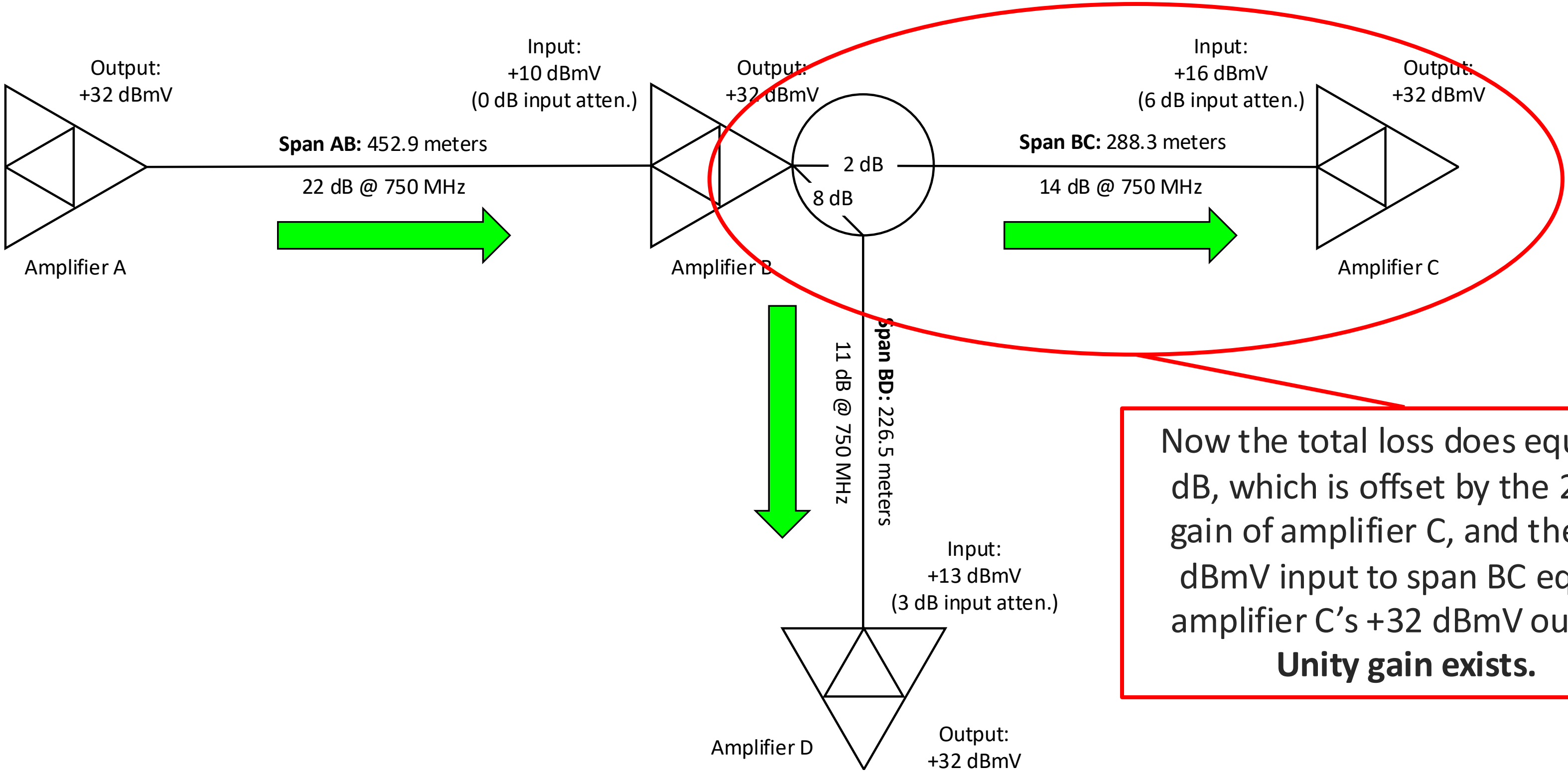
Here we can clearly see that **unity gain exists**, because amplifier B's 22 dB of gain is numerically equal to span AB's 22 dB of loss. As well, the +32 dBmV input to span AB is equal to amplifier B's +32 dBmV output.

Downstream unity gain



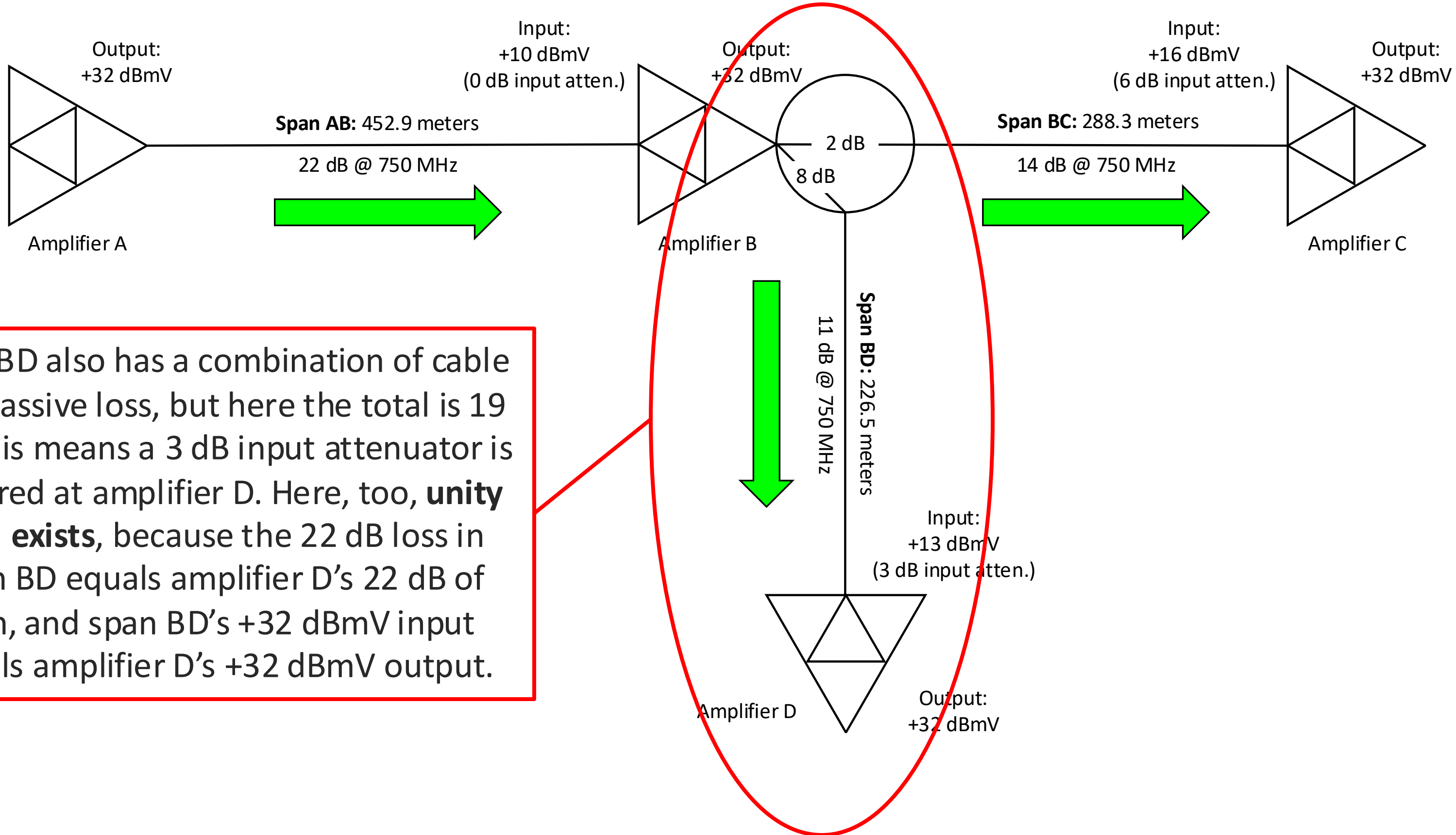
Span BC has a combination of cable and passive loss. The directional coupler's insertion loss is 2 dB, and the cable loss is 14 dB at 750 MHz, for a total of 16 dB. Span BC's loss obviously does not equal the gain of amplifier C, so it's necessary to install a 6 dB input attenuator at amplifier C.

Downstream unity gain



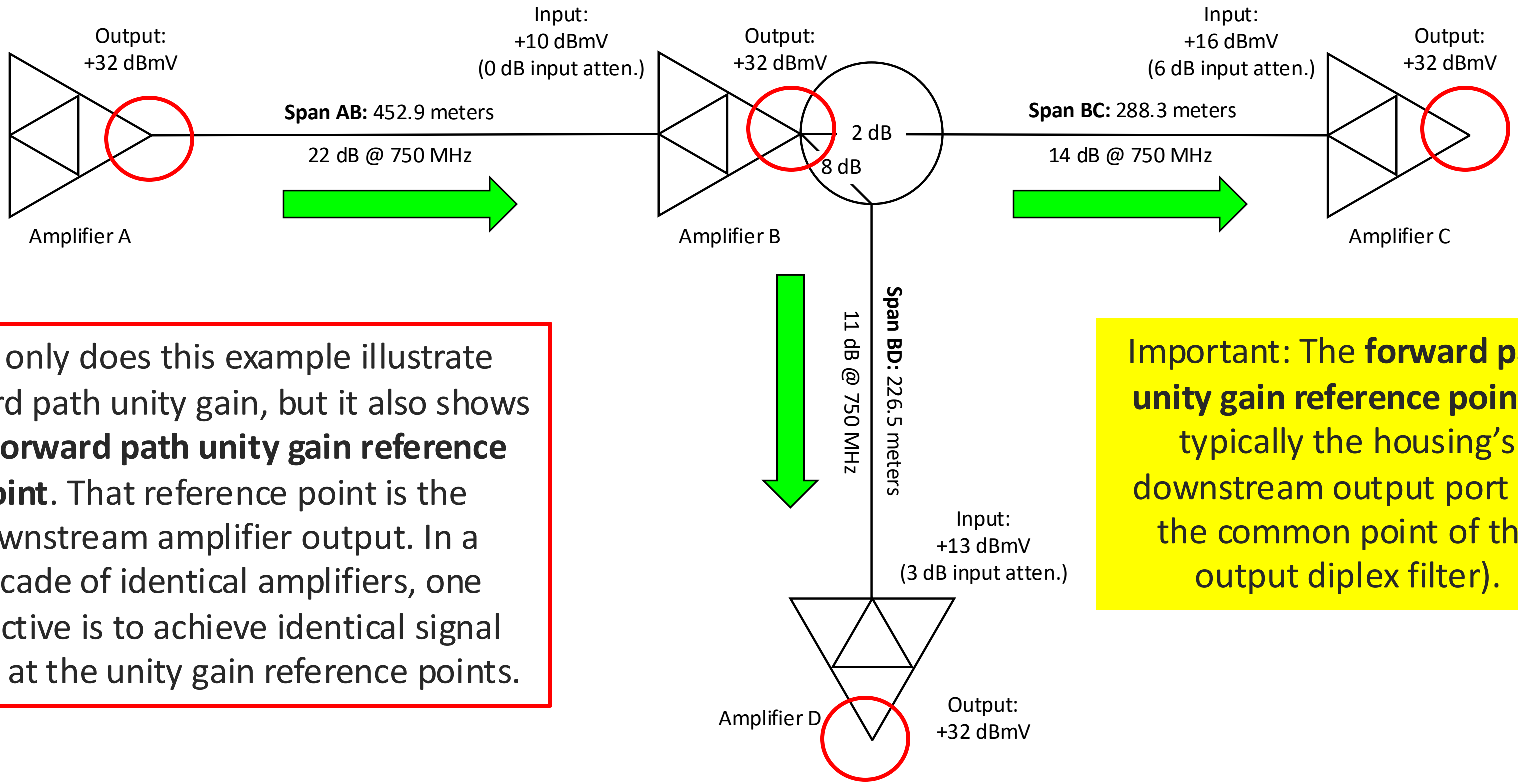
Now the total loss does equal 22 dB, which is offset by the 22 dB gain of amplifier C, and the +32 dBmV input to span BC equals amplifier C's +32 dBmV output. **Unity gain exists.**

Downstream unity gain



Span BD also has a combination of cable and passive loss, but here the total is 19 dB. This means a 3 dB input attenuator is required at amplifier D. Here, too, **unity gain exists**, because the 22 dB loss in span BD equals amplifier D's 22 dB of gain, and span BD's +32 dBmV input equals amplifier D's +32 dBmV output.

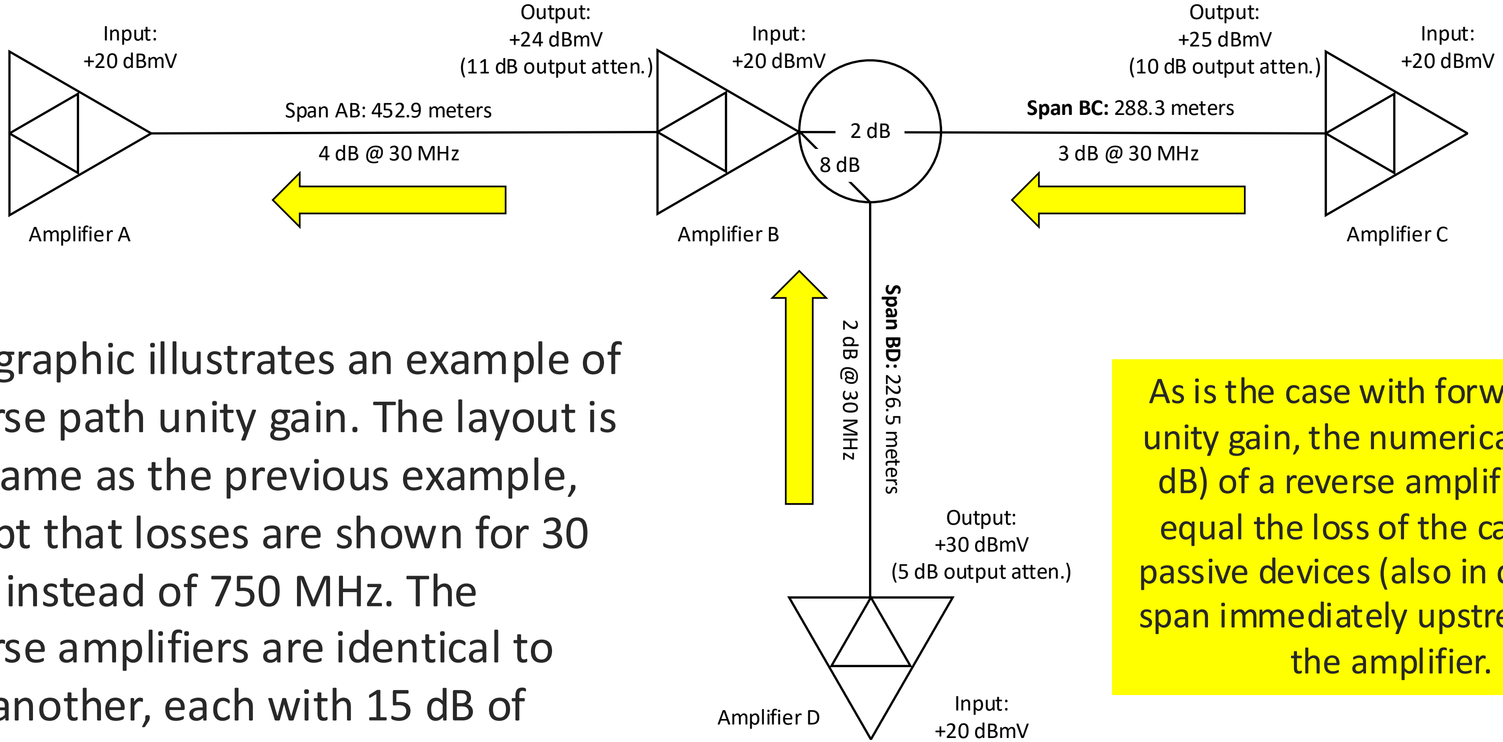
Forward path unity gain reference point



Not only does this example illustrate forward path unity gain, but it also shows the **forward path unity gain reference point**. That reference point is the downstream amplifier output. In a cascade of identical amplifiers, one objective is to achieve identical signal levels at the unity gain reference points.

Important: The **forward path unity gain reference point** is typically the housing's downstream output port (or the common point of the output diplex filter).

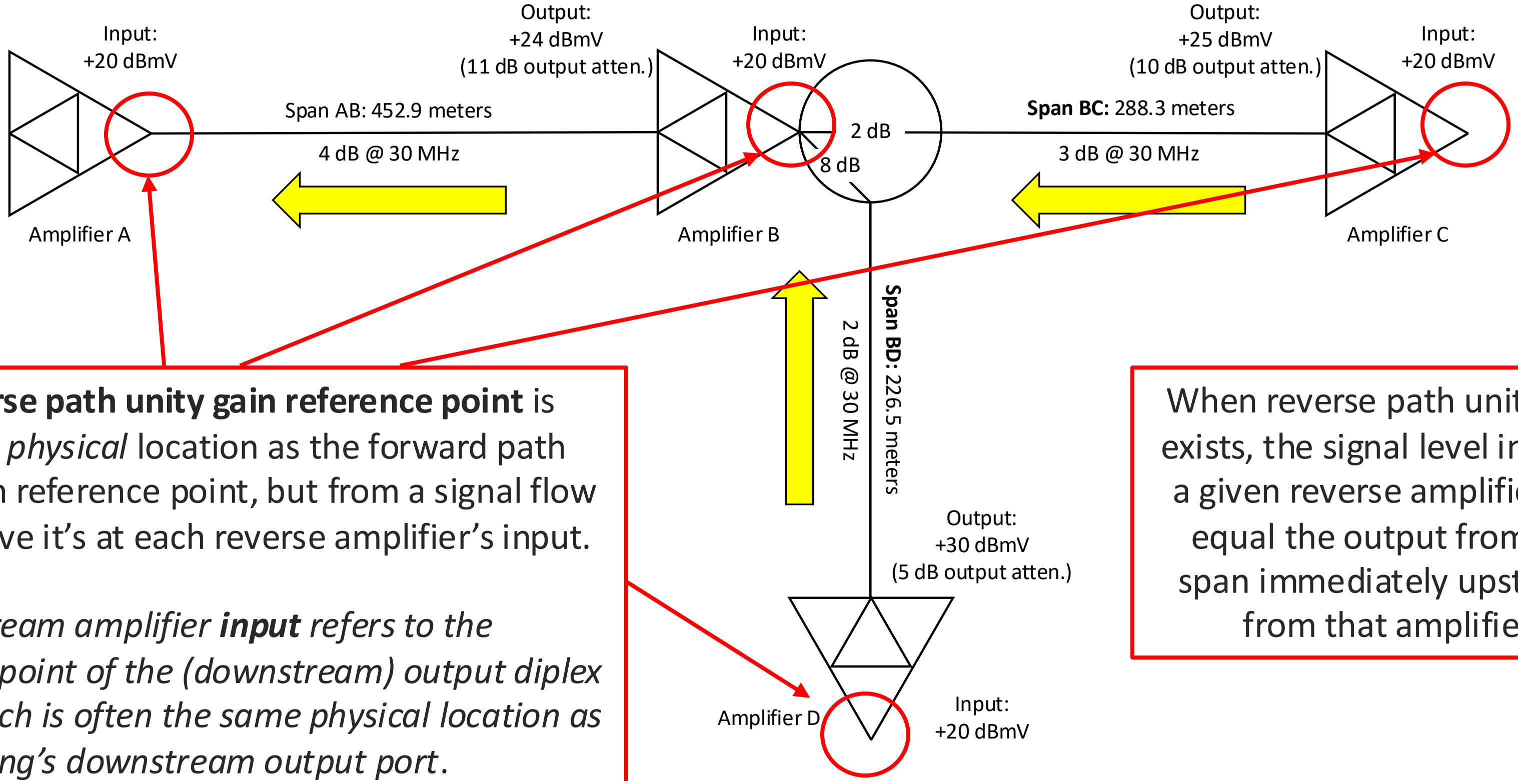
Upstream unity gain



This graphic illustrates an example of reverse path unity gain. The layout is the same as the previous example, except that losses are shown for 30 MHz instead of 750 MHz. The reverse amplifiers are identical to one another, each with 15 dB of gain.

As is the case with forward path unity gain, the numerical gain (in dB) of a reverse amplifier must equal the loss of the cable and passive devices (also in dB) in the span immediately upstream from the amplifier.

Reverse path unity gain reference point

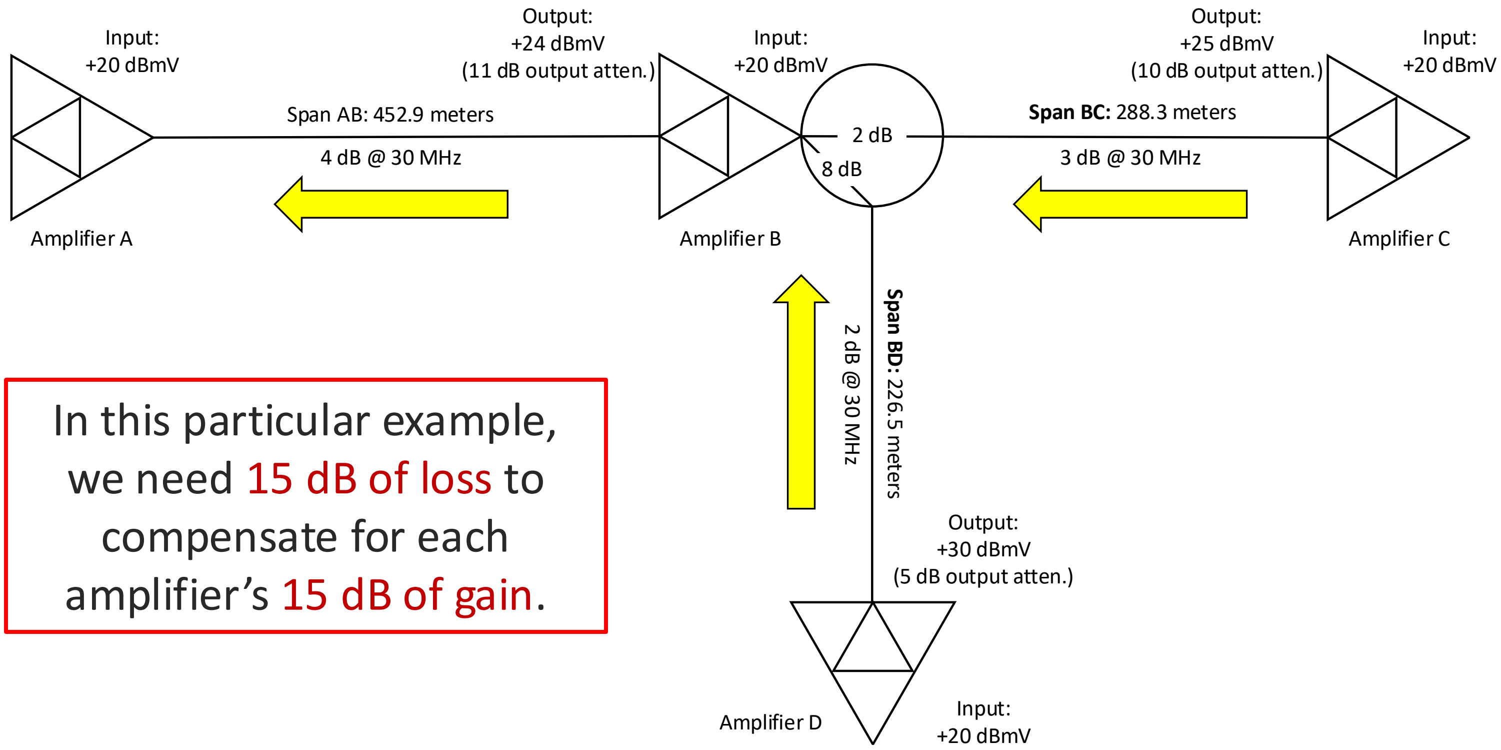


The **reverse path unity gain reference point** is the same *physical* location as the forward path unity gain reference point, but from a signal flow perspective it's at each reverse amplifier's input.

The upstream amplifier ***input*** *refers to the common point of the (downstream) output diplex filter, which is often the same physical location as the housing's downstream output port*.

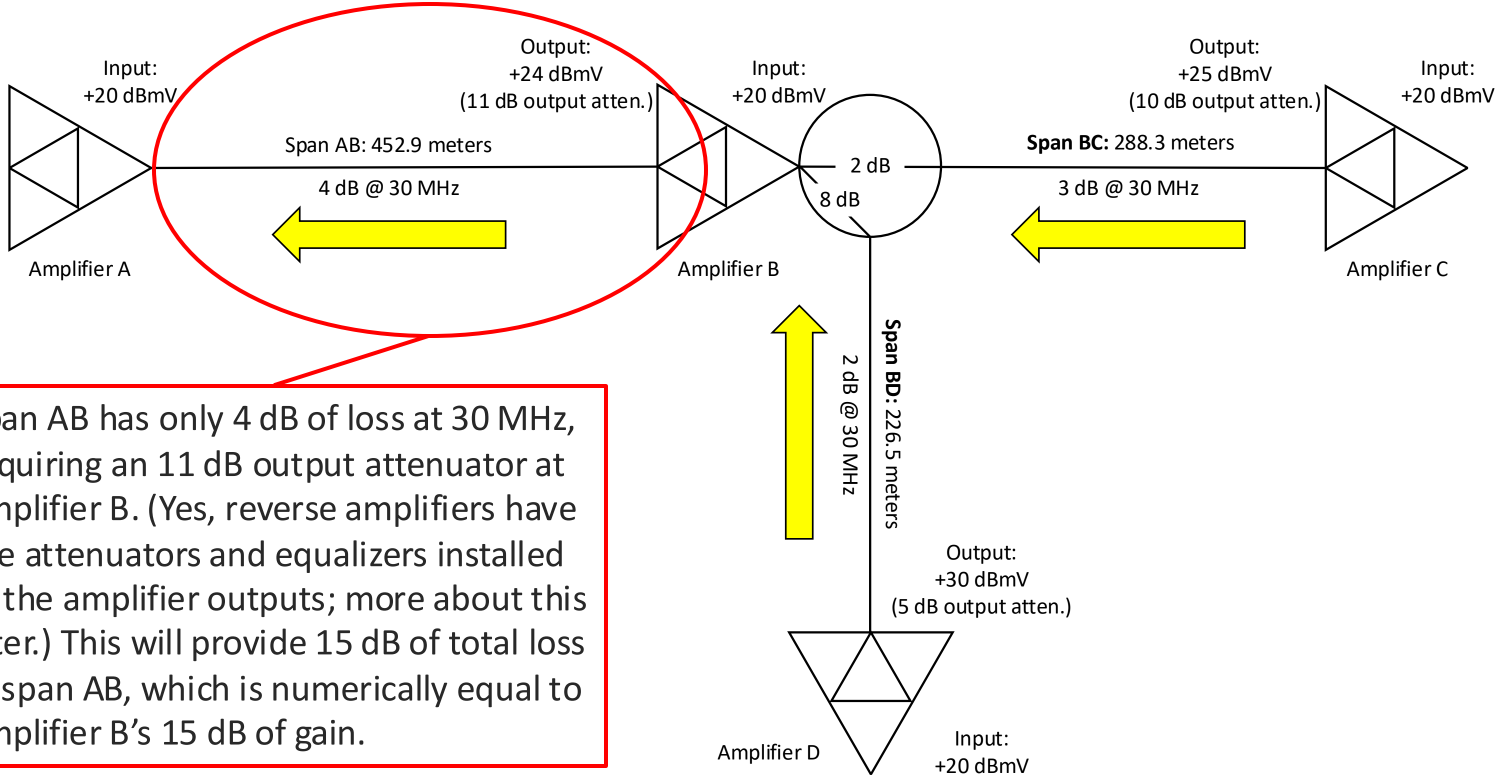
When reverse path unity gain exists, the signal level input to a given reverse amplifier will equal the output from the span immediately upstream from that amplifier.

Upstream unity gain



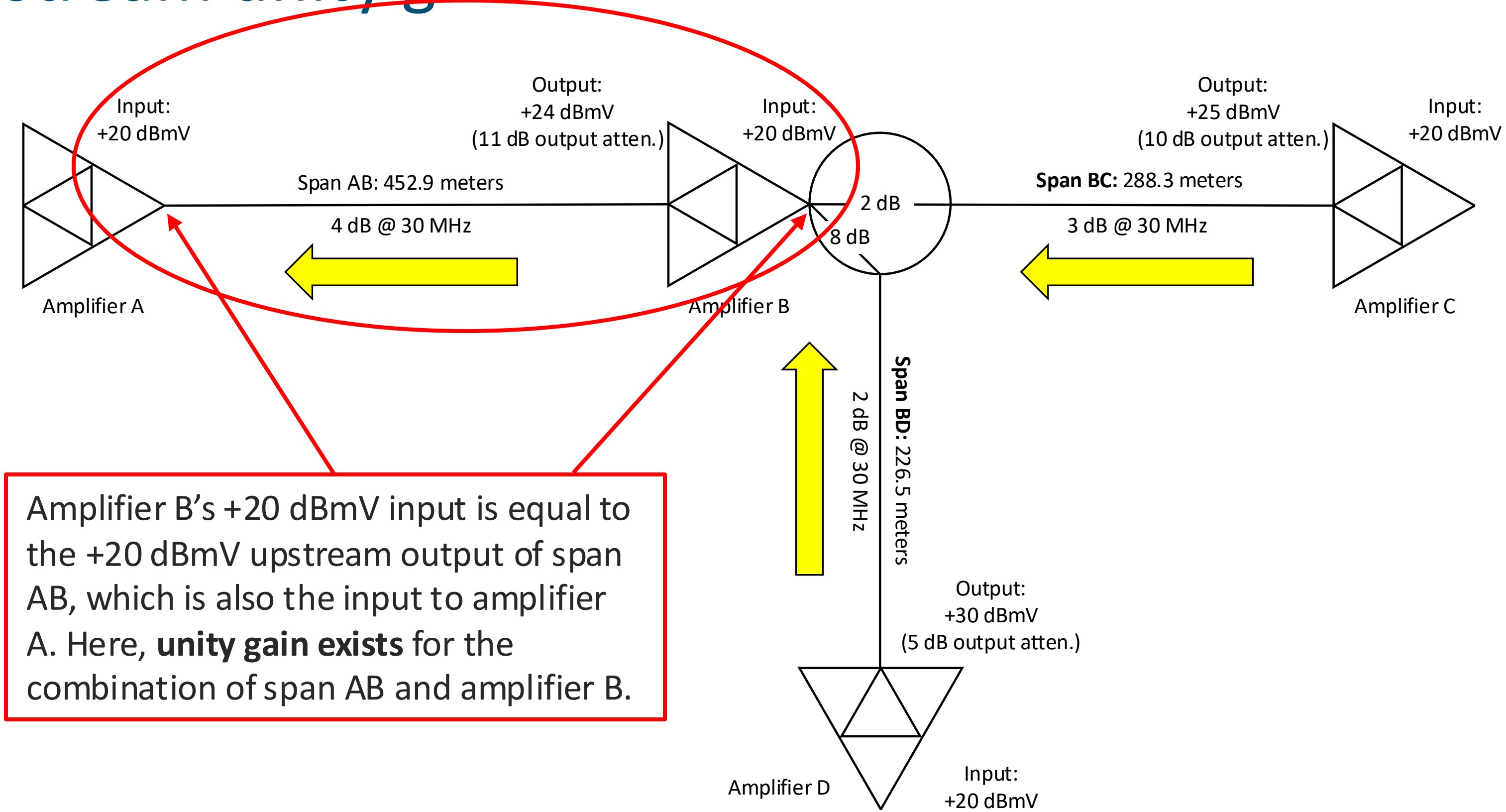
In this particular example, we need 15 dB of loss to compensate for each amplifier's 15 dB of gain.

Upstream unity gain



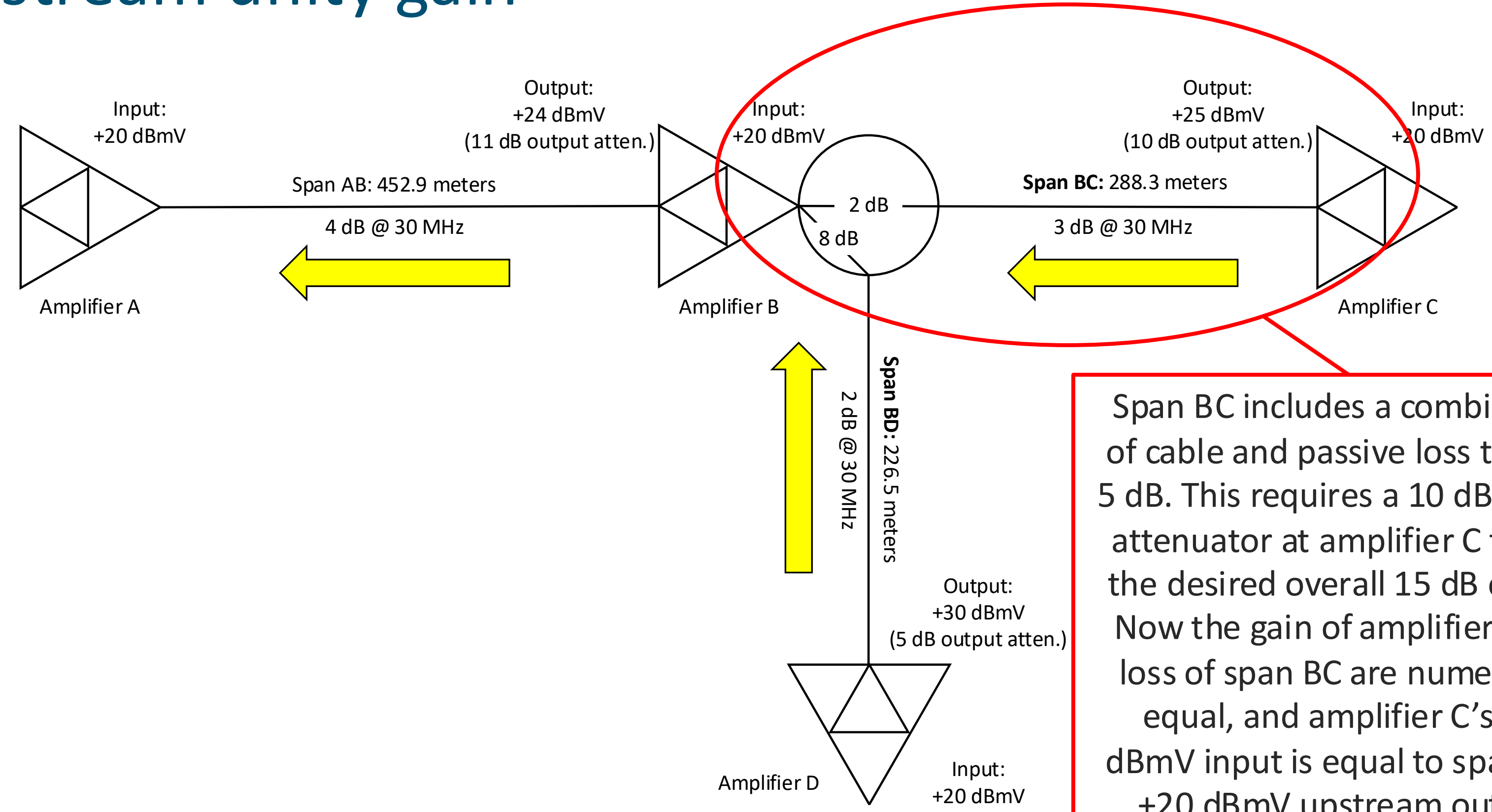
Span AB has only 4 dB of loss at 30 MHz, requiring an 11 dB output attenuator at amplifier B. (Yes, reverse amplifiers have the attenuators and equalizers installed at the amplifier outputs; more about this later.) This will provide 15 dB of total loss in span AB, which is numerically equal to amplifier B's 15 dB of gain.

Upstream unity gain



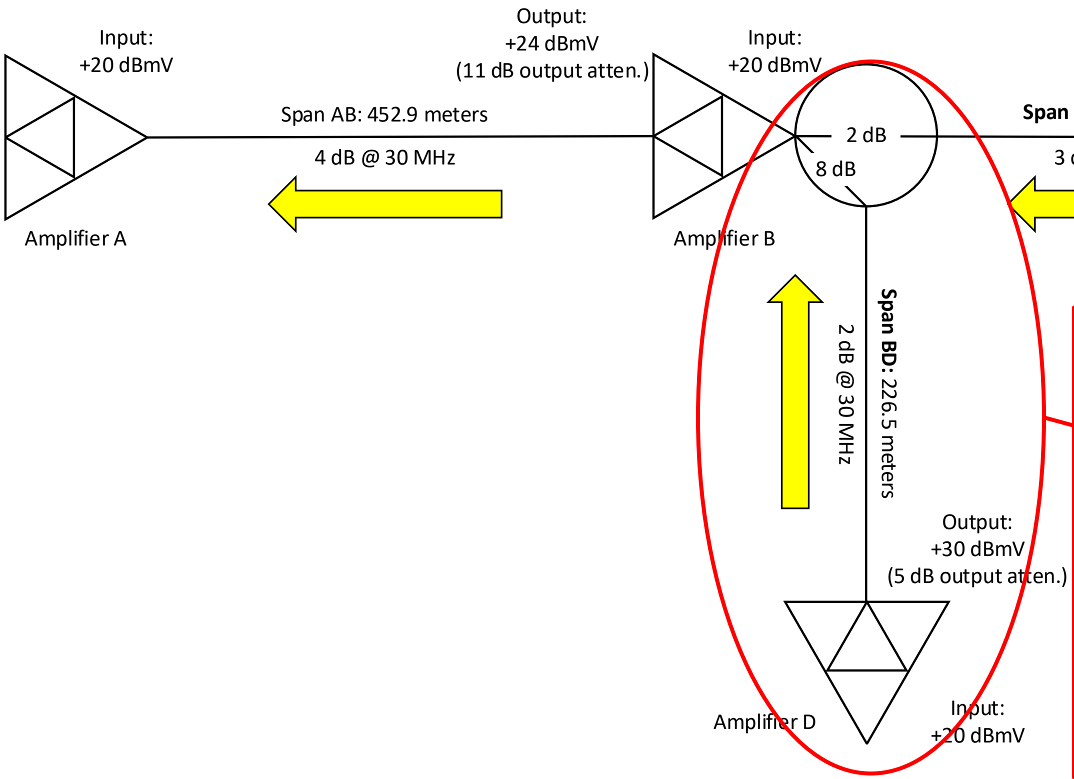
Amplifier B's +20 dBmV input is equal to the +20 dBmV upstream output of span AB, which is also the input to amplifier A. Here, **unity gain exists** for the combination of span AB and amplifier B.

Upstream unity gain



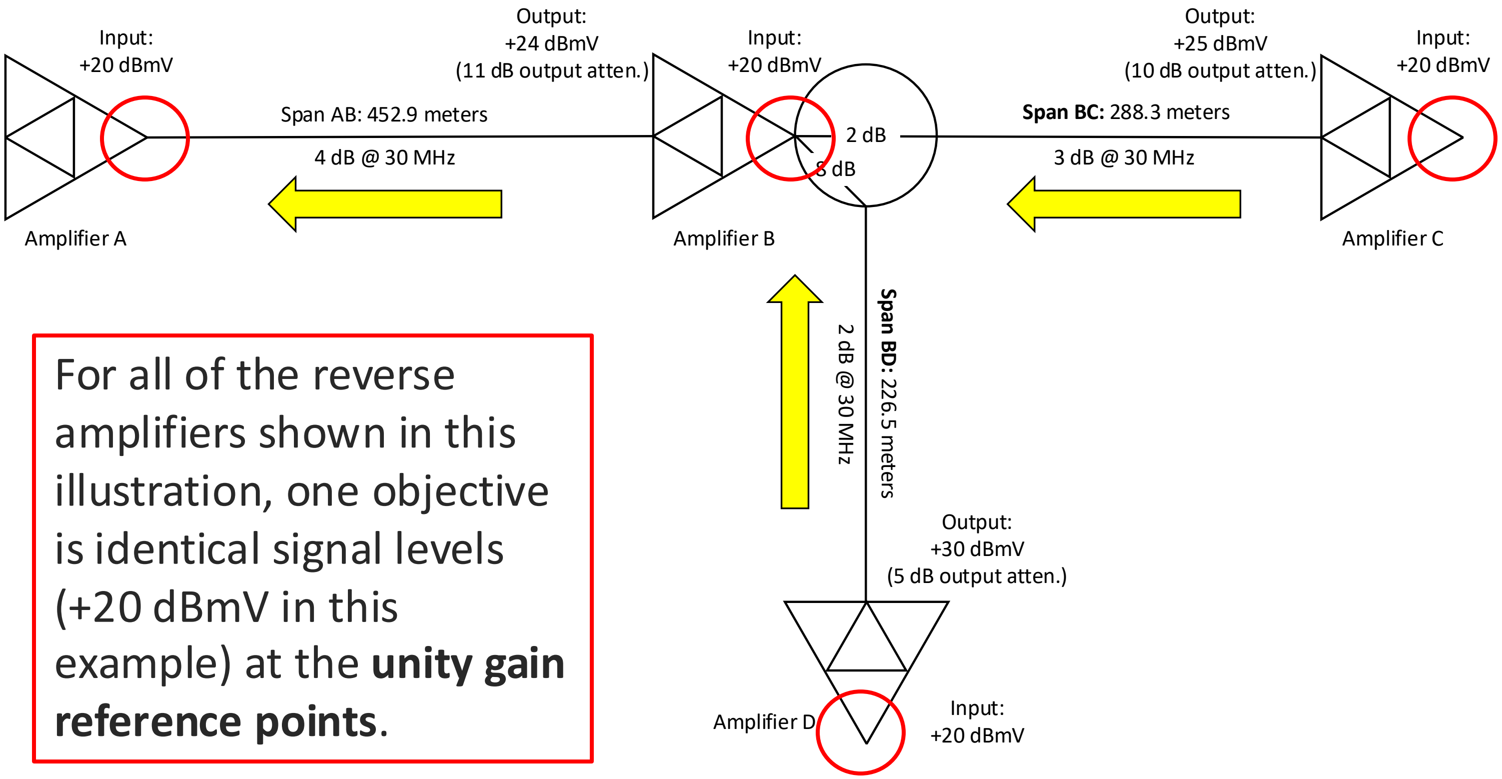
Span BC includes a combination of cable and passive loss totaling 5 dB. This requires a 10 dB output attenuator at amplifier C to give the desired overall 15 dB of loss. Now the gain of amplifier C and loss of span BC are numerically equal, and amplifier C's +20 dBmV input is equal to span BC's +20 dBmV upstream output. **Unity gain exists.**

Upstream unity gain



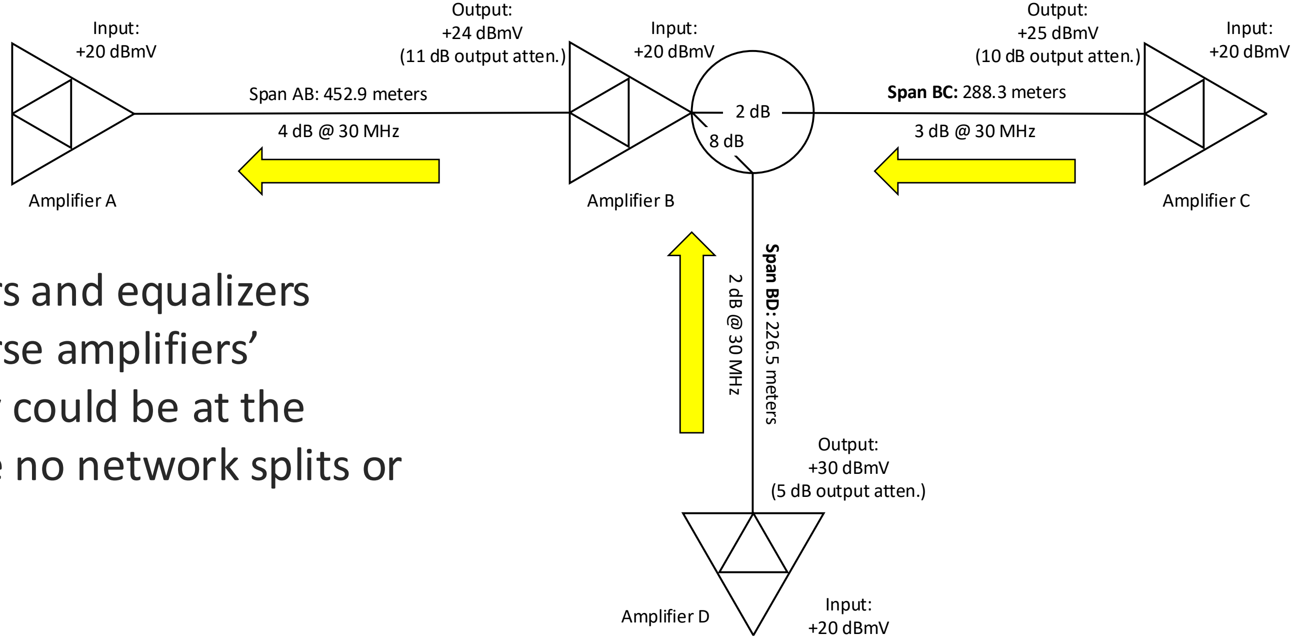
Span BD has 8 dB of passive device loss and only 2 dB of cable loss, requiring a 5 dB output attenuator at amplifier D. This makes the gain of amplifier D and loss of span BD numerically equal (15 dB), and amplifier D's +20 dBmV input equal to span BD's +20 dBmV output. Here, too, **unity gain exists.**

Upstream unity gain



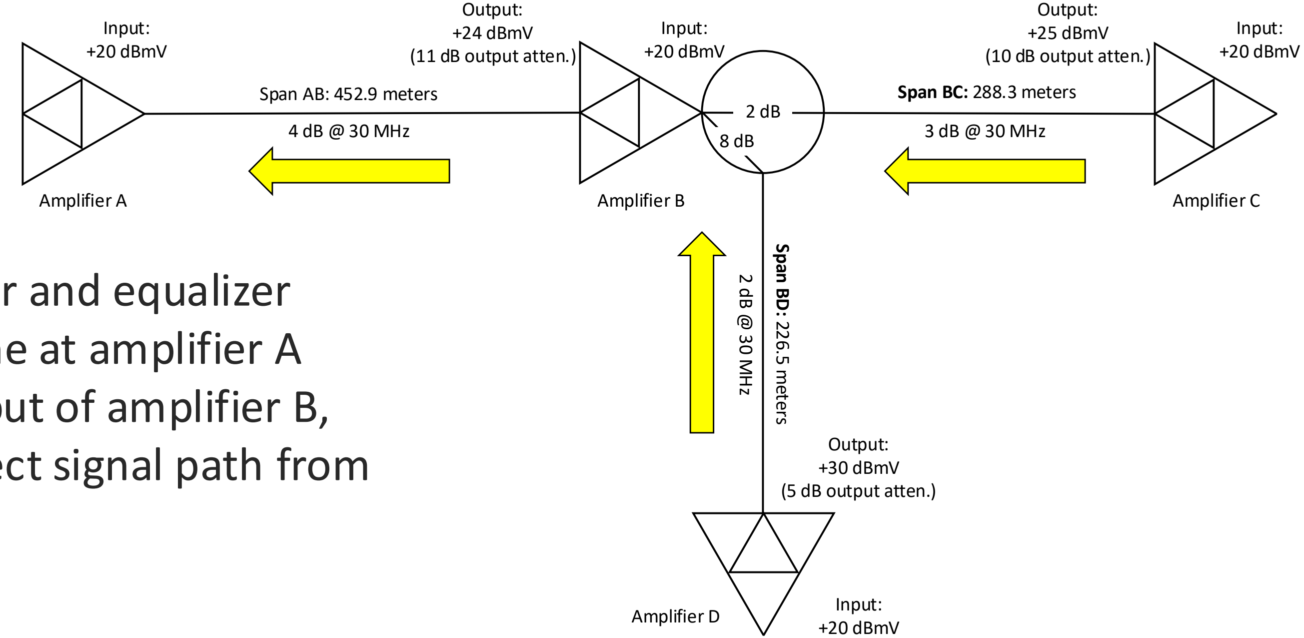
For all of the reverse amplifiers shown in this illustration, one objective is identical signal levels (+20 dBmV in this example) at the **unity gain reference points**.

Upstream attenuator and equalizer location



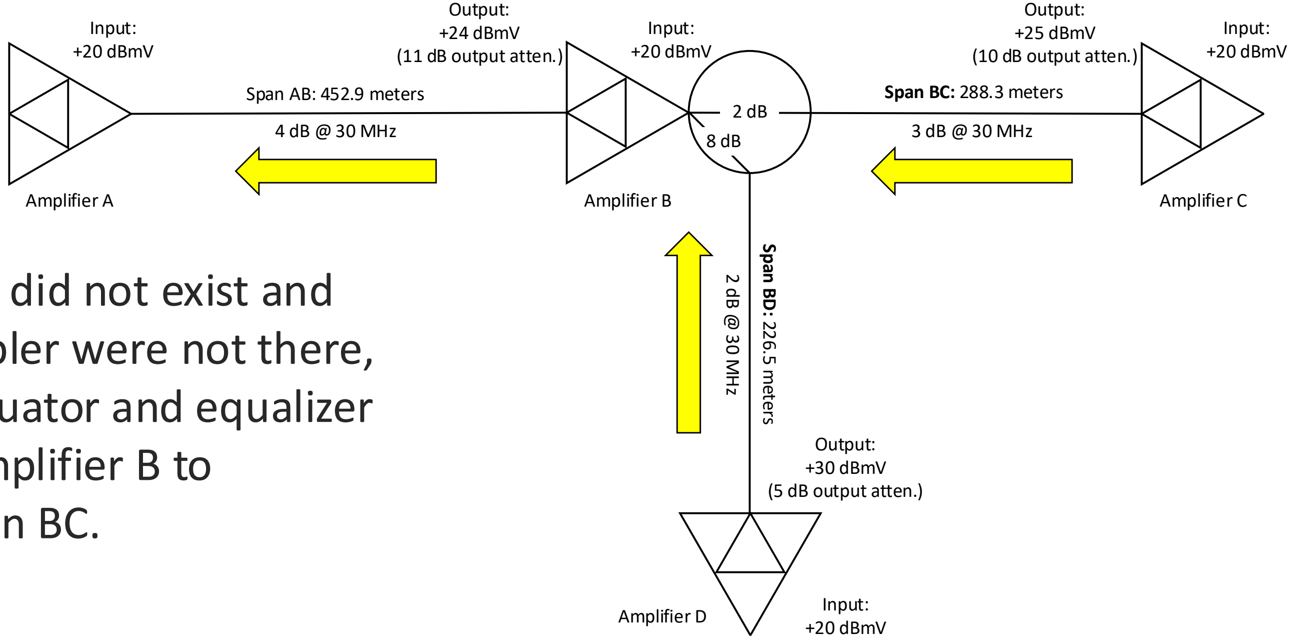
Why are attenuators and equalizers located at the reverse amplifiers' outputs? Well, they could be at the inputs if there were no network splits or branching.

Upstream attenuator and equalizer location



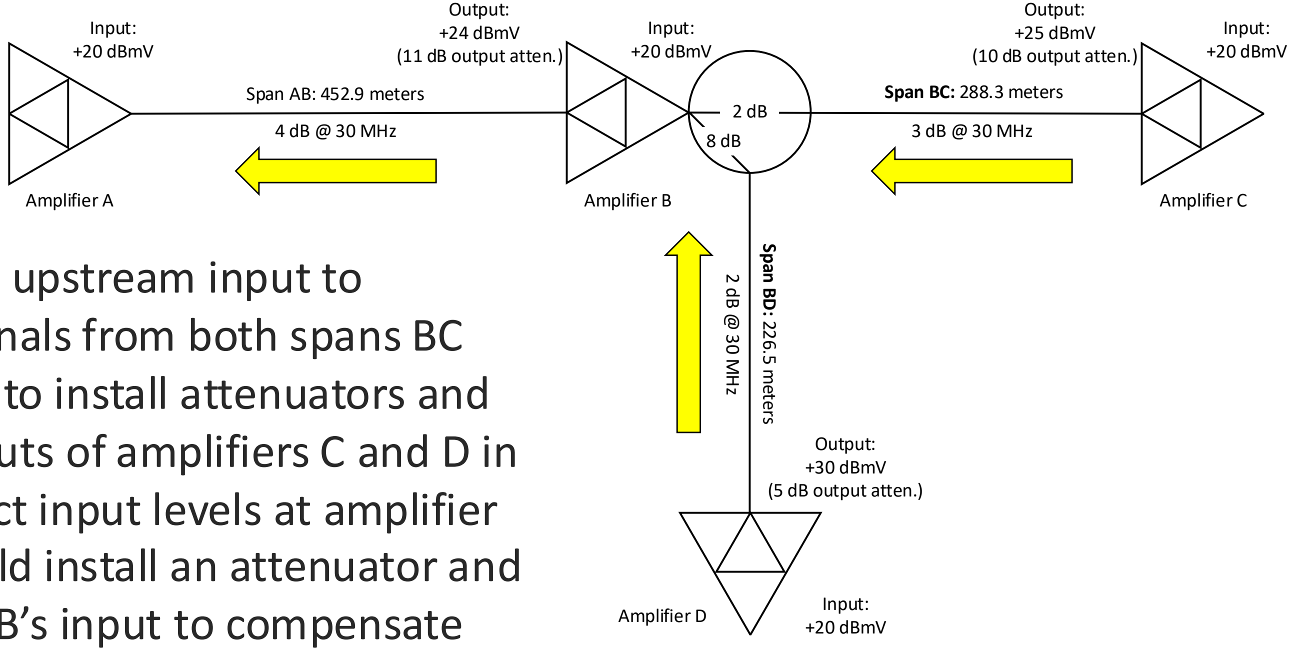
An input attenuator and equalizer would work just fine at amplifier A instead of the output of amplifier B, because of the direct signal path from amplifier B to A.

Upstream attenuator and equalizer location



Likewise, if span BD did not exist and the directional coupler were not there, then an input attenuator and equalizer could be used at amplifier B to compensate for span BC.

Upstream attenuator and equalizer location



However, because the upstream input to amplifier B gets its signals from both spans BC and BD, it's necessary to install attenuators and equalizers at the outputs of amplifiers C and D in order to get the correct input levels at amplifier B. Otherwise, you could install an attenuator and equalizer at amplifier B's input to compensate only for span BC or BD, but not both!

Wrapping up …

Unity gain is an important principle that applies to the forward and reverse paths of every properly designed and operating cable network.

Without it, network performance could be impacted. Unity gain starts in the network design process, and continues through equipment installation, alignment, and on-going operation and maintenance.