A Rocky Mountain Chapter White Paper: "Counting Channels"

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The following is adapted from an article I wrote about calculating channel capacity in cable networks, which originally appeared in the December 2008 issue of *Communications Technology*.

The cable system in which I got my industry start in 1972 boasted a 220 MHz upper frequency limit. The network was based on a tree-and-branch architecture that used Vikoa Futura 12 amplifiers. Those amps were single-ended devices, which meant that despite their roughly 50 MHz to 220 MHz bandwidth, the usable downstream channel capacity was limited to 12: VHF low band channels 2-6, and VHF high band channels 7-13. The theoretical channel capacity was higher, of course, but single-ended amplifiers were distortion-limited to carrying just the 12 broadcast-equivalent VHF TV channels and maybe a few FM stations in the 88 MHz to 108 MHz range.

How can one sort out the channel capacity of a cable network? The first step is to define what a channel is. Unless otherwise indicated, I'm calling a channel a 6 MHz bandwidth chunk of the RF spectrum used to carry a single analog National Television System Committee (NTSC) TV signal.

If we look at those old 220 MHz systems—technically 54 MHz to 216 MHz—the theoretical channel capacity is (216 – 54)/6 = 27 channels. Subtracting the 4 MHz band between channels 4 and 5, and the 20 MHz-wide FM band gives us a more practical number: [(216 – 54) – (4 + 20)]/6 = 23 channels. But we couldn't use the VHF midband (108 MHz to 174 MHz) in single-ended amplifiers—pictures would have been full of interfering beats. With the introduction of push-pull amplifier technology, a so-called 220 MHz system's channel capacity really was 23. Well, sort of. In most instances what we now call channels 98 and 99 (formerly known as channels A-2 and A-1 respectively) weren't counted, so the number of 6 MHz-wide channels was said to be 21. The available channels were 2-6, A-I (now called 14-22), and 7-13.

Over the years the channel capacity of cable networks increased as technology improvements allowed expansion of the upper frequency limit. Some of the more common numbers that I recall include 270 MHz, 300 MHz, 330 MHz, 400 MHz, 450 MHz, 550 MHz, a brief stop at 600 MHz, 750 MHz, 860~870 MHz, and finally 1 GHz. Even though we often said the bandwidth of a system was 270 MHz, 300 MHz, and so on, that's technically incorrect. The total available downstream bandwidth actually is the applicable upper frequency limit minus the lower frequency limit, the latter typically in the 50 MHz to 54 MHz range. While channel 2 (54 MHz to 60 MHz) is the lowest TV channel used in these examples, a bit of usable spectrum is available just below channel 2. That extra few MHz was and still is sometimes used for non-video purposes such as telemetry signals for system sweep equipment (the 4 MHz slot between channels 4 and 5 occasionally sees telemetry, set-top out-of-band, and other non-video signals, too).

Depending on how one counts channel capacity, the numbers of usable channels seemed to vary a bit among manufacturers. For instance, 270 MHz networks were said to support 30 channels, but if channels A-2 and A-1 are included the tally jumps to 32 channels. 300 MHz systems could carry 35 channels (37 channels with A-2 and A-1), 330 MHz bumped the total channel capacity by another five. After 330 MHz, the numbers get a little more interesting.

For instance, what we called 400 MHz systems had a somewhat nebulous upper frequency limit. How's that possible? Well, channel PP (52) ends at 396 MHz, and channel QQ (53) ends at 402 MHz. I remember hearing 400 MHz systems' channel capacity referred to most often as either 52 channels or 54 channels, depending on the manufacturer. If we assume that channel PP (390 MHz to 396 MHz) was the highest used, the channel capacity is 53 channels, or 51 channels without A-2 and A-1. If channel QQ (396 MHz to 402 MHz) is the highest channel, then the capacity is 54 channels with A-2 and A-1, or 52 channels without those two in the total.

For quite a few years the industry continued to use the old letter designations for channels other than 2-6 and 7-13 up through about 450 MHz. Systems designed and built for 450 MHz operation were called 60 channel capable, though when A-2 and A-1 are included the total is 62 channels. Sneaking the last lettered channel into the lineup—channel ZZ (channel 62, or 450 MHz to 456 MHz) bumps the count up one.

The 550 MHz upper frequency limit also is a bit nebulous. Like 400 MHz, there isn't a clean channel break right at 550 MHz. Channel 77 is 540 MHz to 546 MHz, and channel 78 is 546 MHz to 552 MHz. If we use channel 78 as the highest channel, the capacity is [(552 – 54) – (4 + 20)]/6 = 79 channels, including good ol' A-2 (98) and A-1 (99). Drop those two channels, and the capacity is 77 channels. Interestingly, I've heard references to 77 channels, 78 channels, and 79 channels in 550 MHz networks. Where does 78 channels come from? Let's look at some possibilities.

One plausible but unlikely scenario is that the highest channel—channel 78—was mistakenly assumed by someone to be equal to the channel capacity. Oops. The channel count starts with channel 2, not channel 1. The more likely explanation is that channel 77 (540 MHz to 546 MHz) was considered the highest channel, making the capacity 78 channels with A-2 and A-1 in the total. Without A-2 and A-1 the channel capacity is 76 channels. So which is correct? The answer is clearly "it depends," but my vote is for 79 channels.

600 MHz is a little easier. Channel capacity is [(600 – 54) – (4 + 20)]/6 = 87 channels, again including A-2 and A-1. Or 85 channels without A-2 and A-1.

750 MHz works out to [(750 – 54) – (4 + 20)]/6 = 112 channels with A-2 and A-1, or 110 channels without.

860 MHz networks are in the same ballpark as 550 MHz networks, sort of. First, one has to decide just where the upper frequency limit really is. 858 MHz? 860 MHz (no clean channel break at this frequency)? 864 MHz? Or 870 MHz? The latter seems to be the offering *du jour*. An 870 MHz upper frequency limit gives us a channel capacity of [(870 – 54) – (4 + 20)]/6 = 132 channels, here, too, with A-2 and A-1 in the count.

And then there's 1 GHz. This is also one of those problematic frequencies, because there is no clean channel break at 1,000 MHz. Indeed, channel 158 ends at 1,002 MHz. The upper frequency limit may be generically referred to as 1 GHz, but to be technically correct the actual frequency limit is 2 MHz higher. So, a 1,002 MHz upper band edge gives us a channel capacity of [(1,002 – 54) – (4 + 20)]/6 = 154 channels with our old friends A-2 and A-1 included, or 152 channels without. Frankly, it doesn't make sense to leave out those two channels considering the value of RF bandwidth these days, so let's call it what it is: 154 channels.

Muddying all of this up somewhat is the fact that a handful of cable operators have opted to use some of the FM band for carriage of TV or digital signals, upping the channel capacity by another three: channels 95 (A-5), 96 (A-4), and 97 (A-3). These three channels are assigned to 90 MHz to 96 MHz, 96 MHz to 102 MHz, and 102 MHz to 108 MHz respectively. The primary challenge using these three allocations is ingress interference from over-the-air FM broadcast stations.

One more thing: The proper designation for the cable channels used in North America is based upon the Consumer Technology Association's standard CTA-542-D R-2018 *Cable Television Channel Identification Plan*. What many still call "EIA channels" are really "CTA channels." The EIA designation was deprecated quite a few years ago.

Who said counting channels was easy? Now you know why those of us in the engineering side of the business swapped our slide rules for scientific calculators and computer-based spreadsheets.