How Much Coverage Is Too Much Coverage?

aka: What Constitutes 'Repeater' Interference?

1. Obviously (?) aside from 'conditions':
    a. Consider simplex operation - be it .52 or 80 meters... though it's easier to QSY from 52 or an 80 meter frequency ("spin the big knob")
    b. One repeater's (transmit or receive) coverage overlaps another to a point of noticable…
        i. a repeater's transmitter captures over a local system's transmit coverage (how much 'capture' - light to heavy heterodyne in the background or totally wiping out the 'local' repeater's TX?) - TBD
        ii. a user of one repeater whose transmitter presents significant signal to the receiver of another (again, how much signal is too much - light, heavy heterodyne of capture of other repeater's locals?) - “to be determined”
    c. A repeater user’s signal is too close/strong into another repeater’s receiver.

With those questions/conditions/experiences and TBD on the table…

Capture Ratio of the Receiver Is A Significant Factor

Capture ratio of subject receivers must be higher (typically 3-4 dB or greater) and accounted for in planning and coordinating range or other separation between co-channel FM systems.

References:

https://www.rfvenue.com/blog/2014/12/15/making-use-of-the-capture-effect

https://en.wikipedia.org/wiki/Capture_effect

https://www.radiomuseum.org/forum/fm_capture_ratio.html#post245932 (see last entry on the page)

The "To Be Determined" Part

Consider that the (barely?) usable/tolerable sensitivity of a typical amateur radio FM receiver is in the neighborhood of 0.18-0.25uV for 12dB SINAD quieting - that's -121 dBm or S-1. This places the 20dB SINAD (typically full-quieting) level at about 1.6 uV, S4, -103 dBm.

A 3-4 dB (1 S-unit) rejection ratio suggests we can tolerate co-channel signals roughly a single S-unit (6 dB) lower in strength than the signal we are communicating with. The rejection ratio, thus co-channel tolerance we might prefer depends on the design/characteristics/’quality’ of the radio products we use.

Given we're mostly using "ham grade" products, we'd probably prefer 6-12 dB (2-3 S-units) of either receiver rejection ratio, but if that's out of control or not possible with our radios, then we want to have 6-12 dB difference between co-channel signals.

For experience reference, we tend to like/prefer operating stations we hear at least half-scale S5-S6 (-95 dBm) to better S9+ (-73 dBm or less) signals. We're not so inclined to like to hear/be bothered by other on-channel (co-channel) signals of anywhere near S5 or better competing with our usable S5 to S9+ signals..
Given those values, we probably would not want to contend with a co-channel signal at the S-4 to S-5 level - we'd routinely hear heterodyne/warbling in the background.

References:
http://www.astrosurf.com/luxorion/qsl-db-power-units.htm

Since we can't control the characteristics of our receivers, can't always get the local repeater transmitter to increase its power (which could then "cause interference" to the other repeater's users) nor directly control the other repeater's power - a repeater planner and/or coordination group(s) should be working within themselves and others to establish maximum tolerable co-channel coverage/signal levels - physical or RF power 'separation' to avoid 'interference.'

What Signal Levels Are Tolerable to Mitigate Co-Channel 'Interference'?

Assuming we *may* tolerate a non-usable, 'easily' squelch-able "other signal" below S3 (-109 dBm), perhaps better below S2 (-115 dBm) – ?? – we could consider imposing co-channel 'coordination' constraints such that no system(s) have 'overlapping' unusable coverage signal levels greater than -??? dBm amid their adjacent.

Some suggest -100 dBm/S4-S5, others say -120 dBm/S1, others -110 dBm/S2-S3. Some numbers may "work better" or not in different terrains - flat/plains vs quite variable clutter of hills and valleys. Do some sample coverage plots and see what works for your region, keeping in mind the terrain could be different in the next state/region over. In some parts of California we may need a very 'terse' -120 dBm signal limit, in others -100 might work. Maybe -110 dBm works for most and for the "corner cases" we figure it out on a case-by-case basis.

"The number" can be different for Southern California with fewer mountain top radio sites covering a very dense population area with smaller valley regions, than it would be for all or part of Northern California with many mountain top radio sites around and between various broad populated valleys, and of course Central California which is a huge expanse of flat valley surrounded by over a dozen major radio site hilltops that offer RF coverage into other valley areas. It's complicated.

Why dBm instead of S-units? Because most/all commercial/professional and other signal analysis and coverage software deals in dB. S-units, their 6 dB increments are mostly a ham radio thing that does not translate well into various many modulation and signal schemes or analysis.

What If ‘Interference’ Is One Repeater’s User(s) On Another’s Input?

… but other repeater system users accessing more than one repeater…

Other Ways to Apparently Mitigate/Reduce ‘Interference’

There IS a difference between on-same-frequency systems signal presence, and other RF/environmental issues that result in a mysterious on-channel signal not related to another on-channel transmitter.

Likewise there is a difference between mitigating/reducing actual on-/co-channel interference, and only masking RF or other interference/signal annoyances (crud you don’t want coming out of your speaker…)

Many have been wont to believe that CTCSS tones, what Motorola erroneously branded as “Private Line” actually mitigated interference between stations, when in fact it was only and implemented as a way to hamper its business radio customers from acquiring and using non-Motorola products. That lasted only a short time before General Electric, EF Johnson, Kaar, Link and RCA figured out and implemented same/similar tone schemes and began selling into Motorola’s market. So NO, CTCSS, Private Line, Channel Guard, Quiet Channel, Call Guard, Quiet Tone, DCS, etc.offer no security, privacy, etc. to radio use, access, monitoring, etc. Nor do they fix ‘interference.’

Reinforcement/detail relative to tones NOT fixing/preventing interference:
https://www.repeater-builder.com/tech-info/ctcss/ctcss-doesnt-fix-anything.html

If the issue you’re trying to avoid/mitigate is *not* related to same-frequency, but possibly coincident with other off-channel RF signals, systems, then you have to start down the path of intermod (the mixing of two or more signals resulting in unwanted signal presence on one or more other frequencies.)

How and where such mixing occurs (which is also something most/all receivers do to transition RF to humanly usable audio or data…) could be anything from ubiquitously corrosion-prone intermod-mix-point 9913 and LMR style cables to rusty fence wire and posts to bad grounds, or inadequately protected/filtered receiver front-ends, transmitter or PA output stages, etc.

These issues are well beyond the scope of addressing actual co-channel operation. If you are chasing not-on-channel interference - a good place to start:
https://www.softwright.com/faq/support/intermod_finding_solving.html

Pending some coverage mapping graphics to illustrate the major points.

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