Dealing with external interference in a gap filler network

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ROHDE & SCHWARZ

The challenge

Extreme weather conditions and infrastructure changes such as new rail lines, power masts and wind turbines change the echo situation and thus disrupt the transmit operation of gap filler networks. Current gap fillers are not able to independently respond to these changes and are also complex to configure. Conventional gap fillers are increasingly unable to meet the needs and requirements of network operators.

Gap filler network operators desire three things: top signal quality, best reliability and minimal operating costs – all at the same time. But today's products only allow optimizing two of these at most. So if operators demand very good signal quality and high reliability, they need to invest a lot of time and work to frequently reconfigure the echo cancellation settings. This needs to be done on the gap filler site utilizing a measurement setup to identify the current echo situation. Naturally, this results in high operating costs. In another example, an operator demands low operating costs and still good signal quality. That might cause regular muting effects when Doppler echoes occur because the applied echo cancellation settings do not handle dynamic echoes well.

Let's talk about issues and options.

The issue at hand:
external interference

At fjords and mountain valleys the problem is most obvious: terrestrially broadcast TV signals from a distant transmitter do not make it all the way to the valley floor, leaving the population there without coverage unless additional steps are taken. Installing complete low-power transmitters at such locations with baseband signal feeding via data network or satellite is generally not an economically viable option – especially since the number of transmitters required can grow very quickly. Instead, the standard practice is to use repeaters that operate in relay mode. They receive the signal at an elevated position from the air, just like a normal TV receiver, and rebroadcast the signal towards the valley floor.

Depending on whether the same frequency or a different frequency is used, the following distinctions are made:
◗ Transposer: a repeater converts the received signal to a different frequency.
◗ Retransmitter: like a transposer but with signal regeneration. The received signal is demodulated and reconstructed.
◗ Gap filler: a gap filler or on-channel repeater transmits on the same frequency on which it receives the signal (signal frequency network [SFN] application).

Because the transmitted frequency is the same as the received frequency, gap fillers suffer from a problem that does not occur when transmitters with independent signal feeding are used: echoes, i.e. disruptive signal feedback to the input. The rugged topology of typical places where gap fillers are used has many vertical reflecting surfaces, which exacerbates the problem. A compounding factor is the constricted nature of these locations, where everything happens in a relatively confined space. As a result, the distance from the transmitter to the reflecting objects and back is so short that the resulting echo signals are still of significant strength, overlaying the actual source signal and disturbing it. Until now, there has been no all-embracing satisfactory solution to this problem.

One issue is that echoes are caused not just by natural obstacles but also by moving objects such as vehicles. The Doppler echoes resulting from moving objects are very hard to counteract because of their sporadic and unpredictable nature. Moreover, any structural changes that occurred – for example if a road bridge or a wind farm was built, which invariably causes a change in the echo situation – meant that the maintenance team had to analyze the new situation and reconfigure the echo cancellation mechanism on site.

Unfortunately, the new configuration could also become obsolete at any instant, e.g. at the start of rush hour or when the wind turbines began to turn faster. A poor Doppler echo performance or a generally high noise contribution by signal processing could have consequences ranging from signal degradation to transmission failure. In such cases, the operator was forced to choose between two evils: either use strict echo cancellation to ensure continuous transmission while accepting permanently poor signal quality, or opt for high quality and live with occasional broadcast interruptions.

Daily issues for gap filler networks

Today, gap filler network operators face many challenges caused by the limitations of today's gap filler products:

❙ High MER degradation
❙ Weak Doppler echo performance
❙ Difficult echo cancellation configuration
❙ Not robust in adjacent channel scenarios
❙ Cannot handle changing echo situations

This results in serious problems gap filler networks face every day. Normal external influences can corrupt the signal. Doppler echoes caused by passing trucks or even small cars can influence the MER. Some operators do not trust the reliability of gap fillers, because their MER performance depends too much on outside conditions. Muting of gap fillers is not uncommon, which operators accept as a common effect.

Since the vulnerability of gap fillers to external influences made it difficult to predict how they would behave when installed at specific transmitter sites, operators found it impossible to reliably plan their networks. For instance, a gap filler from supplier A might never work properly at a certain location despite repeated efforts, while the model from supplier B would not have these problems. At other locations, however, this situation might be the reverse. Even seasonal weather causes problems. There may not be an appropriate static echo cancellation setting that suits both winter and summer.

Gap filler sites cannot be planned, since possible effects cannot reliably be identified prior to installation. Furthermore, some gap filler network operators visit their gap filler sites every three months in order to review them and to adapt gap filler settings that handle changing echo situations.
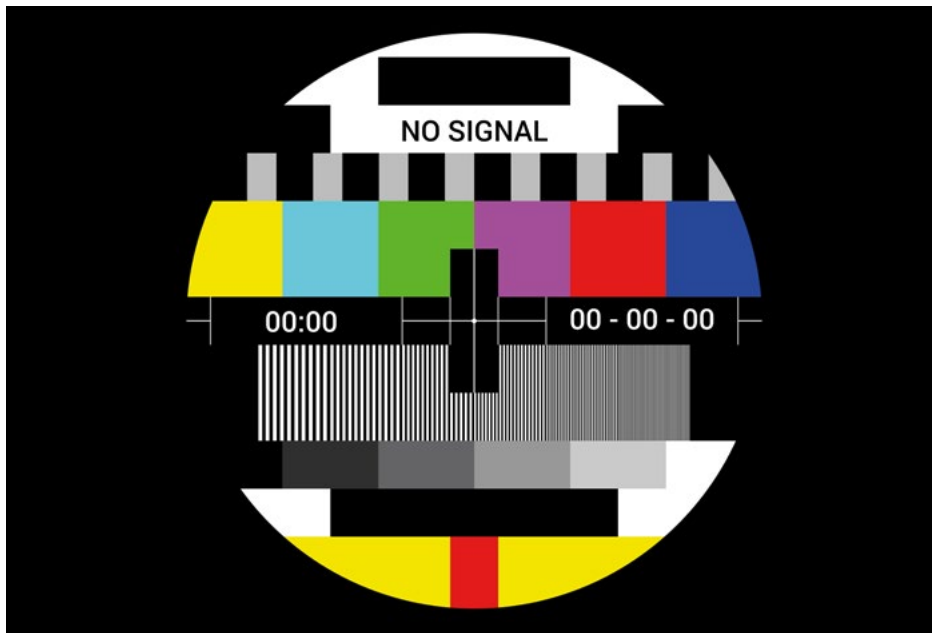
What does the R&S®TLU9 GapFiller do that the others can't?

The R&S®TLU9 GapFiller scores top marks for outstanding signal quality in every situation, strong performance even with Doppler echoes, and uninterrupted transmission for maximum reliability. It dramatically reduces maintenance effort and associated operating costs for network operators.

The R&S®TLU9 GapFiller is by far the best available rebroadcasting product for SFN applications. It provides a world-class echo cancellation mechanism, which puts the key focus on best possible signal quality in any echo scenario. The brand-new R&S®smartEC feature is the first and only to provide a new approach

to handling Doppler echoes by optimizing the R&S®TLU9 GapFiller settings in changing echo situations, continuously and in realtime. It offers unparalleled robustness and a signal quality level that up until now was considered impossible.

The R&S®TLU9 GapFiller not only provides superb performance parameters, it also changes the way of operation. It is highly resistant to outside influences, and the R&S®smartEC feature does away with the need for recurrent corrections of EC settings. R&S®smartEC turns the R&S®TLU9 GapFiller into an "install-and-forget" product that nevertheless is far more reliable and provides a much higher signal quality than any other product known in the market.

That creates new degrees of freedom concerning the operating model of gap filler networks and makes it possible to deploy gap fillers in scenarios where only low-power transmitters could be used before.

Let's have a look at the details.

Challenges ahead – and addressed

The R&S®TLU9 GapFiller provides four key features to address the aforementioned challenges:

ı An integrated input filter for a crystal-clear input signal freed from emissions of adjacent channels
ı A unique echo cancellation mechanism to maximize the signal quality
ı A flexible and straightforward way to configure the echo cancellation mechanism
ı The brand-new R&S®smartEC feature, which significantly improves echo cancellation performance for Doppler echoes and radically simplifies the operation of gap fillers

Integrated input filter with extremely sharp filter edges

The R&S®TLU9 GapFiller provides an advanced combination of analog and digital filtering to clean the relevant input signal from influences of neighboring channels. The development target was to eliminate the need for an external input filter even for strong adjacent channel scenarios. An improved SAW filter was combined with strong digital filters and placed in a very early stage of the signal processing chain.

That ensures that the level of the input signal can be kept high and stable without the danger of overdriving components of the subsequent chain, e.g. in case of dynamic effects of neighboring channels. As a result, the R&S®TLU9 GapFiller provides an adjacent channel suppression of 80 dB at fc ±4.115 MHz, which leads to at least 50 dB lower neighboring levels (compared with the actual input signal level).

Furthermore, the input filtering stage of the R&S®TLU9 GapFiller includes an LTE filter that erases the negative influence of mirrored LTE signals to the input frequency of the gap filler.
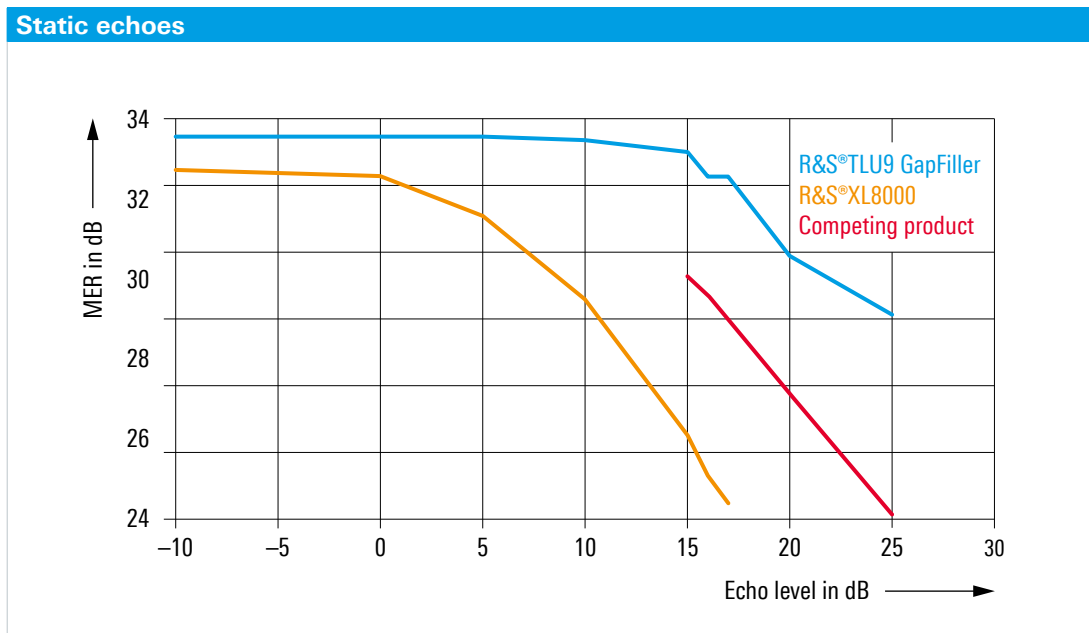
Adjacent channel suppression of 80 dB at ±4.115 MHz

−50 dB

80 dB

Channel n-1   Channel n   Channel n+1
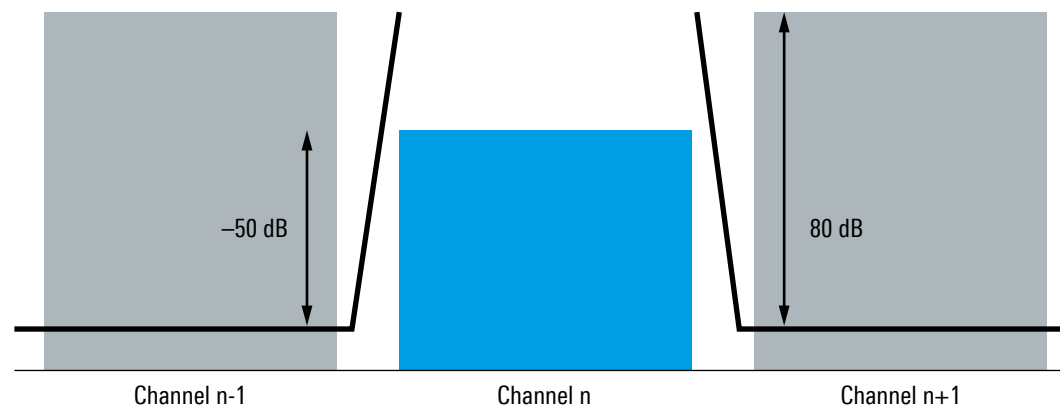
Unique echo cancellation mechanism

The R&S®TLU9 GapFiller provides an excellent echo cancellation mechanism that stably handles strong echoes up to +25 dB echo gain as well as multiple echoes. What makes its echo cancellation mechanism unique is the strong focus on delivering the best possible signal quality in any echo scenario.

For static echo scenarios, the highly advanced design of the echo cancellation mechanism and the use of premium components significantly improves signal quality by up to 7 dB higher MER compared with the previous Rohde&Schwarz model and up to 5 dB higher MER values compared with recognized competing products. For echo levels up to +15 dB echo gain, there is no significant influence on signal quality, which is consistently higher than 33 dB MER. Even for +25 dB echo gain, the R&S®TLU9 GapFiller provides very good signal quality of more than 29 dB MER, which is much higher than any other product on the market can deliver.

Static echoes

Legend:
R&S®TLU9 GapFiller
R&S®XL8000
Competing product

Y-axis: MER in dB (24, 26, 28, 30, 32, 34)
X-axis: Echo level in dB (−10, −5, 0, 5, 10, 15, 20, 25, 30)

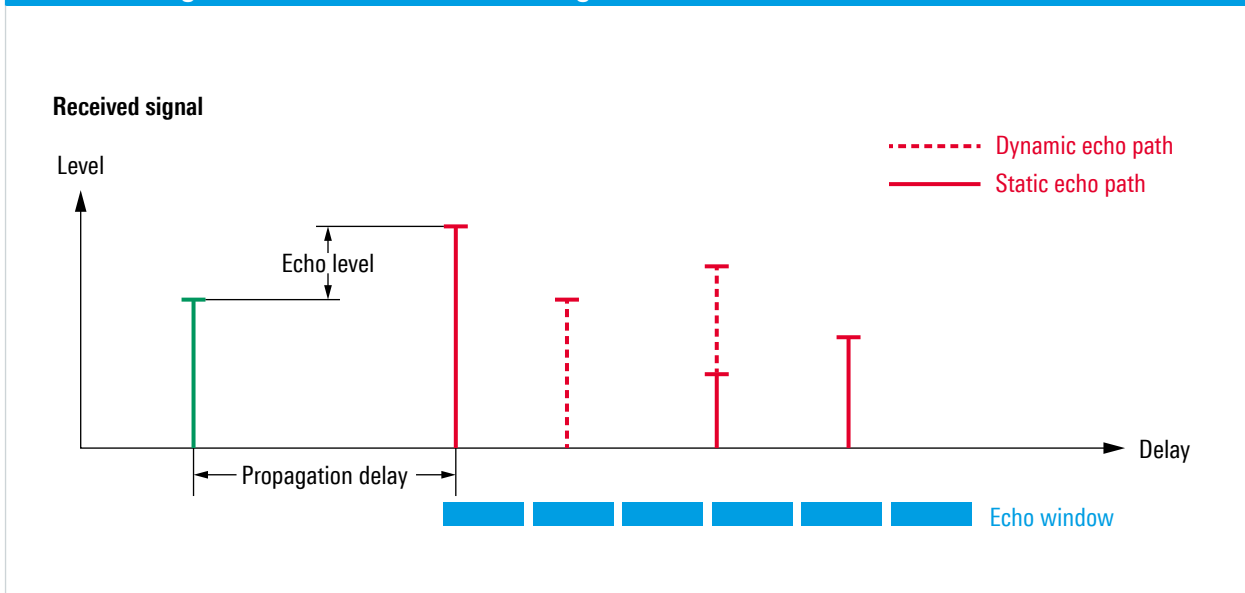The R&S®TLU9 GapFiller provides MER values well above any alternative product.

Flexible echo window design

The R&S®TLU9 GapFiller provides a big echo window size of 17 μs. But in this case, size is not necessarily beneficial. The high noise contribution of a big echo window inevitably leads to a weak signal quality. Also a high step size (or convergence rate of the echo cancellation algorithm) is disruptive to the signal quality. It is therefore a real challenge to provide both a big echo window and an excellent signal quality at the same time.

The solution is to apply as much echo window as necessary but also to apply an echo window as small as possible. The R&S®TLU9 GapFiller manages that by providing several echo window segments that can be configured individually. This makes it possible to handle each echo path differently according to its characteristics. Segments without echo paths may be configured with a very low step size, which hardly influences the signal quality at all. Segments with static echoes may be configured with a low to medium step size, while segments with Doppler echo need to be configured with a high or very high step size.

This approach ensures the solid cancellation of different echo types and provides the best possible signal quality even for multiple echoes with different characteristics. Which, in turn, ensures maximum signal quality at all times for the given situation.

Flexible configuration of six echo window segments

Received signal

Level

Dynamic echo path

Static echo path

Echo level

Propagation delay

Delay

Echo window

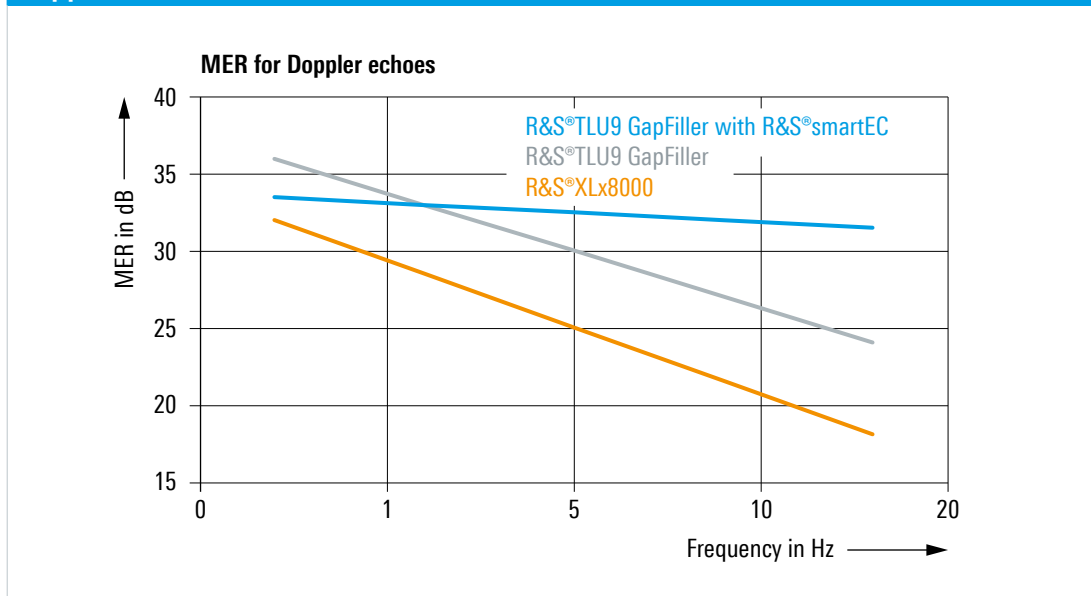# R&S®smartEC: optimal echo cancellation – anytime and immediately

The dynamics of a gap filler site's environment, such as the construction of new buildings, changing weather conditions or even bypassing traffic, remain an unsolved problem. Some of these influences change on a daily basis and may result in unexpected Doppler echoes or new static echo paths. Such effects cannot be handled appropriately by static echo cancellation settings. Even frequent reconfigurations on site cannot address these effects.

To tackle this issue, the R&S®TLU9 GapFiller provides a first-of-its-kind feature, R&S®smartEC. This brand-new software continuously analyzes the current echo situation and finds the best possible settings for each situation in realtime.

With R&S®smartEC, the echo cancellation mechanism may be configured for a single static echo path in one second and instantly change to a new configuration. This suits a strong multipath Doppler echo scenario, if such a scenario occurs, in the next second. All of this occurs fully automatically and self-adaptively within microseconds without any interruption of the transmission or a collapse of the signal quality.

The result is an unparalleled robustness and a signal quality level that up until now was considered impossible. For instance, for a Doppler echo with 20 Hz Doppler frequency, the new R&S®smartEC feature provides a MER at least 10 dB higher than that of the previous Rohde & Schwarz model. This makes a huge difference for network operators and can motivate them to install a gap filler instead of a low-power transmitter.

Doppler echoes

MER for Doppler echoes

R&S®TLU9 GapFiller with R&S®smartEC
R&S®TLU9 GapFiller
R&S®XLx8000

The R&S®TLU9 GapFiller generally delivers improved performance compared with its predecessor, the R&S®XLx8000. With R&S®smartEC, it provides optimal echo cancellation with excellent signal quality, anytime and continuously.

Resulting benefits for gap filler network operators

The R&S®TLU9 GapFiller provides exactly what a gap filler network needs. On the one hand, network operators have an obligation to their customers, the program providers, who want to make sure their viewers have high-quality coverage. On the other hand, the actual costs required to achieve and maintain high network quality should be as low as possible. These issues can be reconciled only if the gap fillers deliver high-quality signals under all operating conditions. At the same time, the gap fillers must support the required level of predictability and make it easier to schedule and ensure low operating costs.

❚ Maximized signal quality
❚ Minimized influence of outside conditions on MER
❚ No need for regular modification of EC setting
❚ Reliable signal transmission
❚ Deterministic planning of gap filler performance

The new R&S®smartEC feature turns the R&S®TLU9 GapFiller into an "install-and-forget" product that nevertheless is far more reliable and provides a much higher signal quality than any other product known in the market. That creates new degrees of freedom concerning the operating model of gap filler networks and makes it possible to deploy gap fillers in scenarios where only low-power transmitters could be used before. As a result, R&S®smartEC can significantly reduce operating costs.
In short, R&S®TLU9 GapFiller fulfills broadcast customers' key needs: top signal quality, best reliability and minimal operating costs.

The R&S®TLU9 GapFiller takes rebroadcasting to a future level.

About Rohde & Schwarz
The Rohde & Schwarz electronics group offers innovative solutions in the following business fields: test and measurement, broadcast and media, secure communications, cybersecurity, monitoring and network testing. Founded more than 80 years ago, the independent company which is headquartered in Munich, Germany, has an extensive sales and service network with locations in more than 70 countries.

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