An Efficient Filtering Technique of Gap Filler System for Multi-standards Digital Terrestrial TV in an SFN

El Miloud Ar-Reyouchi

Department of Telecommunication and Computer Science, Abdelmalek Essaadi University, Morocco
e.arreyouchi@m.ieice.org

Abstract

This paper presents and describes an efficient technique for canceling echoes and isolating the receiving and transmitting antennas for all generations of Digital Terrestrial Television (DTT) System in a Single Frequency Network (SFN) using the same input and output channel. We aim to improve the intelligibility of the essential parameters of DTT gap filer (GF) systems, especially the Modulation error ratio (MER), by canceling out echoes with optimizing coverage areas. We propose an efficient Filtering Technique EFT of GF with two echoes canceling, surface acoustic wave (SAW) filter, and LTE filter by applying as much echo window as necessary, including an echo window as small as possible. The EFT of GF provides and manages several echo windows that can be configured independently. We consider this filtering technique as the best echo canceller is existing, allowing the cancellation of high echo levels, perfect isolation antennas with an optimum output MER. It outperforms current techniques with complete echo cancellation accompanying improvement percentage, which varies between 7% and 39%.

Keywords: Gap filler, Efficient filtering technique, Modulation error ratio, Single frequency network

1 Introduction

Generally, the necessary practical DTT network planning uses the gap fillers (GFs), which can be foreseen to cover shaded areas of the weak-signal. GFs receive the signal from the main transmitter and amplify it for re-rebroadcasting in SFN using the same radio-frequency channel. On the other side, the implementation of the coded orthogonal frequency division multiplexing (COFDM) techniques [1-2] allows the GFs to re-use the same frequency of the primary transmitter. The advantage of this technique is its lower cost and creating SFN, which is most commonly used for economizing frequency congestion [3]. The presence of a guard interval (GI) [4], in COFDM, gives it excellent robustness to lute against echoes and interference derived from multipath interference. The suitable selection of GI parameter [5] able to provide resilience against delayed interference caused by the multiple received signals. Moreover, the GI value has a significant implication on the topology. Its duration governs the maximum echo delay permissible by the system, and it commands the maximum possible distance between co-channel transmitters accordingly.

In SFN (Gap-Fillers), the correct positioning of the TX and RX antennas is always necessary to reduce the interference, echoes, and to seek maximum isolation between receiving and broadcasting antennas.

The coincidence of several TV broadcasts produces different types of echoes, whether artificial or natural. The repetitions may appear when receiving simultaneously the same channel from several transmitters [6]. Another reason that can cause echoes is the reflection of the signal on large objects such as mountains.

To improve high area performance applying SFN synchronization, the studies in [7-9] have treated various network architectures depending on different parameters like OFDM technology, the selected scattering power, and suitable antennas [10]. Echoes can also be decreased by decreasing the number of emitters per local area. The selection of a TV transmitter with multiple antennas to the transmission and reception MIMO (multiple inputs, multiple outputs) [11-12] heights they can promote smooth operation of the self-interference cancellation technique

Many studies have explored different aspects of the behavioral feedback path, such as [13]. The echo cancellation method has been studied for a long time, such as [14-16]. The Very High-Performance Echo Canceller (VHPEC) GF work proposed in [17] provides three configurable cancellation gaps with a big echo window size of 18 µs, up to 37,6µs, and finally, a window which can cancel any echo present in the cancellation gap (multipath propagation). The three windows can shift independently in a range going up to 37, 6 µs. The FIR digital filter [18] can also suppress the echoes; in [19], the authors have proposed the filtering algorithm, which is suitable for digital mobile

*Corresponding Author: El Miloud Ar-Reyouchi; E-mail: e.arreyouchi@m.ieice.org
DOI: 10.3966/160792642020092105009

terminals and the field of the internet of things [20-21]. To reduce the interference of redundant information in a geographic context, the authors in [22] propose an algorithm based on redundant data deletion and filtering technology.

Nevertheless, generally, size is not in every situation advantageous. The high signal degradation existence of a big echo window unavoidably prorogues to weak signal quality. Also, a tall step size (or convergence rate of the echo cancellation algorithm) degenerates the signal quality. Therefore, it poses a severe challenge to provide both a big echo window and an exceptional signal quality simultaneously.

The proposed EFT can suppress Doppler Effect and echoes with a more considerable gain margin (higher echo levels), providing an optimum MER performance. The DTT widely requires MER for OFDM signal performance in SFN [23], whose Subcarrier spacing differs from that of narrowband [24].

In this paper, the EFT includes two excellent echo cancellation as a critical electronic signal filtering to solve the echo and interference problem in the SFN, namely surface acoustic wave (SAW) filters and LTE filter. Furthermore, the EFT technique should be compared with other research results, Adaptive gap filler (AGF), such as [25]. The proposed technology does not only ensure the isolation between the receiving and transmitting antennas of multi-standards DTT in an SFN, standard gap filler (SGF) [26] but also can suppress Doppler Effect and avoid the interferences and echoes overall. It has to be noted that the applied Echo cancellation [27] techniques not only help to improve isolation [28] but also gives perfect emission-reception separation. Our goal is to get satisfaction levels of 80-85% of a parameter, which have a direct relationship with the echoes suppression, especially the MER. The EFT also has the benefit of very powerful filtering to reject adjacent channels that traditional GF may not have been able to process effectively.

The main objective of this technique is to form a filter technique to become familiar with the process of canceling echoes and to cancel system feedback isolating the receiving and transmitting antennas. Also, this technique allows the GFs to bring outstanding compactness, high efficiency, and smart installation.

The remaining of this paper is classified as follows. In the second Section, we briefly introduce a general system Performance. The third Section exposes and discusses the problem with the remedy. The fourth Section provides a functional description of the Efficient Filtering Technique. The fifth Section deals with the summary of the simulation results obtained. Finally, the sixth Section presents conclusions.

2 General Performance

The transmission path is known as "Rician channel," which takes into consideration the effect of multipath signals, noise, and the dominating direct signal path between Tx and Rx.

Considering $S(t)$ as the transmitted complex signal having a carrier frequency f_0 modulated by a baseband complex signal $x(t)$, and it can be written as: $S(\mathrm{t}) = x(t).e^{j2\pi f_0 t}$.

The addition of a reflected signal on a direct signal negatively influences the reception level. Multipath propagation interference is a phenomenon that often leads to a variation in intensity signal inter-symbol interference (ISI). These cases are modeled in a Rice channel, in which the Gaussian channel and its specific characteristics also be present. The received signal suffers a multipath channel with distinct waves. In the case of additive white Gaussian noise excluded, it can become as:

$$S^{'}(\mathrm{t}) = \sum_{i=1}^{m} a_i(t) S(t - \tau_i(t) \quad \textbf{(1)}$$

which give the following equations:

$$S^{'}(\mathrm{t}) = \sum_{i=1}^{m} a_i(t).e^{-j2\pi f_0 \tau_i(t)}.x(t - \tau_i(t)).e^{j2\pi f_0 t} \quad \textbf{(2)}$$

where $a_i(\mathrm{t}) = \beta_i(\mathrm{t}).e^{\alpha_i(\mathrm{t})}$, and $\alpha_i(\mathrm{t})$ indicate the attenuation and the delay of the i-th path. The received signal $S^{'}(\mathrm{t})$ can be reformed as the baseband signal $y(t)$:

$$y(\mathrm{t}) = \sum_{i}^{m} c_i(t) x(t - \tau_i(t) \quad \textbf{(3)}$$

where

$$c_i(\mathrm{t}) = a_i(t) e^{-j2\pi f_0 \tau_i(t)} \quad \textbf{(4)}$$

The Doppler shift affects the attenuation $a_i(t)$ periodically and is relatively small when compared with the carrier frequency f_0.

A simulation of the power requirements for DTT, such as Digital Video Broadcasting - Terrestrial first and 2e generation (DVB-T/T2) standard, applied the following mathematical model to describe the channels with echoes. In the Rician channel model, the Gaussian channel exists as well as its characteristics. The received signal $y(t)$ is assembled from signals reflection arrived from different paths, according to [29], it becomes:

$$y(t) = \frac{\rho_0 x(t) + \sum_{i=1}^{m} \rho_i e^{-j2\pi\alpha_i} x(t - \tau_i)}{\sqrt{\sum_{i=0}^{m} \rho^2{}_i}} \quad \textbf{(5)}$$

The following equation represents the description of the signal influence of Rayleigh channel:

$$y(t)=\frac{\sum_{i=1}^{m}\rho_i e^{-j2\pi\alpha_i}x(t-\tau_i)}{\sqrt{\sum_{i=0}^{m}\rho^2{}_i}} \quad \textbf{(6)}$$

where ρ_0 is the attenuation in the line of sight(LOS) propagation of the DTT transmitter, as DVB-T/T2, ρ_i is the attenuation in echo path i, θ_i is the phase rotation in the echo part i, and τ_i is the relative delay time in the echo part. The following equation gives the Rice Factor K:

$$K=\frac{\rho_0}{\sum_{i=1}^{m}\rho^2{}_i} \quad \textbf{(7)}$$

K defines the signal ratio by way of the LOS broadcasting path to the sum in all different echo ways.

There are many performance parameters such as MER, BER, Intermodulation (IMD), C/N, and RF Level that can be used to evaluate the quality of the service (QoS) for DVB-H/T/T2 reception. The most useful one is the MER, which is used to quantify the performance of a DTT, namely: transmitters, repeaters, and gap fillers. It provides a clear and fast overview of the echoes and overlaps measurements; therefore, we will highlight the MER.

In the OFDM system, a random bit sequence is generated, and then the bits are mapped into 64-QAM symbols. The I and Q values of this sequence are stored as the $\tilde{I}_j$ and $\tilde{Q}_j$ array. The $\tilde{I}_j$ and $\tilde{Q}_j$ array is next used to form the OFDM frequency domain signal, in which the resulting OFDM symbols I_j Q_j are mapped.

MER measurement of OFDM in SFN is used to measure the modulation quality [30], and practically its value is enough (according to measurements made on SFN) to judge the absence or the presence of the echoes in SFN.

MER over several symbols N (is the number of points in a measurement) is defined as:

$$MER=\frac{\sum_{j=1}^{N}(\tilde{I}_j^2+\tilde{Q}_J^2)}{\sum_{j=1}^{N}\left[(I_j-\tilde{I}_j)^2+(Q_j-\tilde{Q}_j)^2\right]} \quad \textbf{(9)}$$

where: I_j, Q_j, $\tilde{I}_j$, $\tilde{Q}_j$ are the ideal and quadrature components of the jth measured/ referenced OFDM signal, respectively.

3 Descriptions of Problems and Remedy Solution

3.1 Problematic

Nowadays, the GF network exploiters encounter many difficulties caused by the limitations of conventional GF products:

- High MER defacement
- Fragile Doppler echo accomplishment
- Complexity echo cancellation configuration
- Fragility in adjacent channel scenarios
- It does not manage to change echo situations.
- RF coupling between the broadcast signal from the antenna patterns of broadcasting stations and the signal picked up by the receiving antenna

If the coupling level is too high, this turns into a precarious, risky, and challenging situation that can easily destruct the equipment hardware due to the positive return path. In the case where the GF is located within an SFN, The problem becomes even more complicated. To remedy this problem, we use an exceptional Digital Echo Canceller in the digital processing module of a GF.

In the SFN overlap area, the weaker of the received signals from multipath directions is deemed considered as an echo. Thanks to the global positioning system (GPS), the synchronization of the transmitters of the broadcasting centers allows echoes to be placed precisely at guard intervals (GI) which length depends on the duration of the echoes.

The problem worsens considerably, and the COFDM [31] remedy that it suggested, however, does not readily apply in domains where the user density is low impediments such as distance and terrain create challenging obstacles to conventional approaches to the DTT network. The overview of DVB standards, namely DVB-T/H/T2, was not able to solve the echoes squarely and overlaps phenomenon using COFDM techniques. From a physical point of view, the Overlap effects (between the antennas) are inevitable.

3.2 Remedy

For sound isolation between the Tx and Rx antennas, the solution is a digital echo cancellation based on a software solution of an echo canceller GFs that can resolve the most challenging echo conditions. Therefore, to limit isolation between the Rx and Tx antennas and suppress echoes with interference in SFN, the EFT GF can optionally incorporate two echoes canceling, SAW, and LTE filters.

EFT is a powerful and useful tool to remove echoes whose gain margin (GM) level can reach up -10 dB. Moreover, especially in SFN operation, and in severe reception conditions, EFT can remove multipath propagation impacts by equalizing the amplitude distortions of the GF received distorted signal spectrum that is created by very near echoes.

The EFT is also able to suppress echoes but with considerable GM where the echo levels exceed the input signal by 24 dB and can often remove Doppler Effect. EFT is integrated to avoid multipath, as well as Doppler echoes. The GF cancels feedback echoes with a GM up to 24dB, and three gaps echo giving a selective cancellation that would go until 37,6μs.

Gap Filler station requires different considerations during Installation time. The fact that a domestic receiver gets demodulate the signal does not mean that the signal has sufficient quality to be processed and retransmitted by the Gap Filler, as several parameters must be measured. Various aspects should be taken into account before starting the installation of a Gap Filler.

On the other side, disadvantages come from the output power limitations due to stability problems caused by the non-perfect isolation of the transmit/receive antennas and the reflections from the surrounding environment. To achieve a sound input/output isolation, usually, the transmit/receive antennas are placed far apart on the antenna masts, as illustrated in Figure 1.

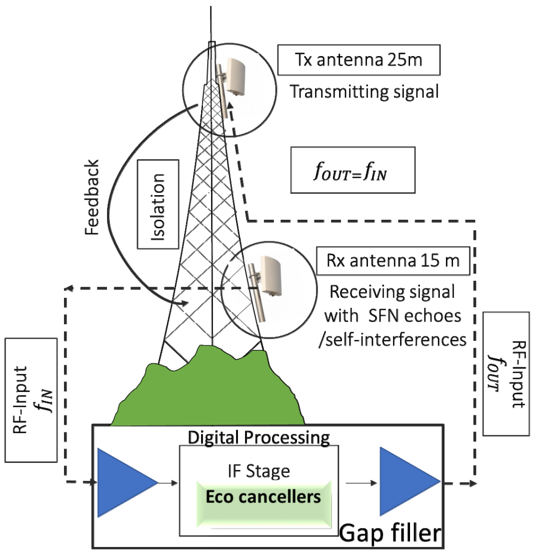

Figure 1. Correct positioning of the TX and RX antennas seeking maximum isolation

Figure 1 shows the block diagram representation of the digital Gap filler internal composition and the correct positioning of the receiving Rx and the transmitting antennas system. The system carries out a down-conversion of the receiving RF signal to an intermediate frequency (IF), filters the resulting signal, and reconverts it back to RF that it is amplified before rebroadcasting starts.

We select the Rx antenna position to at least 15 meters away from the TX antenna (if possible), building a proper impedance matching [32] network. We try to target the Tx and Rx antennas for opposite sides. Also, EFT GF, echo cancellation, is applied to combat echoes from the output of the system fed back into the input.

An excellent remedy beneficial to solve this challenge is to use as much echo window adjustable and configurable as necessary. Simultaneously, it can also specify an echo window as small as possible. The EFT GF controls and administers the filtering operation by providing several echo windows that can be configured

These configurations are the most common gap positions, which can cover a wide variety of cancellation scenarios. ETF GF facilitates to handle each echo path discretely according to its specific characteristics. Windows without echo paths may be configured with a shallow step size, which hardly influences the signal quality at all. Window echo with static echoes may be set with a low to medium step size, while windows with Doppler echo need to be configured with a high or very high step size. The filter used in the IF range is constructed as a surface acoustic wave (SAW) filters and LTE filters.

This approach allows the GF network to guarantee the fundamental cancellation of distinct echo sorts. It also offers excellent and maximum signal quality, even for multiple reaching echoes with different characteristics and for the given permanent situation.

The flexibility of window configuration makes EFT GF durable against Doppler echoes and interrupted transmission.

4 Efficient Filtering Technique Functional Description

Figure 2 shows the principle setup of an EFT GF and its operational diagram. The principle idea of the proposed technique is to apply as much echo window as necessary with an echo window as small as possible. The EFT GF succeeds in its management by offering several echo windows that can be configured separately. In Figure 2 illustrates the flexible configuration of seven echo cancellation windows.

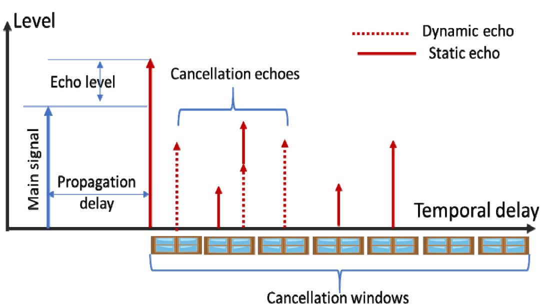

Figure 2. Adjustable configuration of seven echo window

This proposal makes it possible to treat each echo path differently according to its specific characteristics. In the case of windows without echo, they may be configured with the particulars set. Echo windows with static echoes may be fixed with a low to medium step size, while windows with Doppler echo need to be configured with a high or very high step size.

When the echo signal level inferior to the first signal, the EFT GF can work without any echo canceller in SFN. In the case where reception conditions are particularly tricky in SFN, the need for EFT GF for an echo signal level for echo signal level higher than the original signal is fundamental.

4.1 SAW Surface Acoustic Wave Filter: Technical Representation

The conventional filters used in this range are constructed as surface acoustic wave (SAW) filters SAW filter for better sideband suppression (adjacent channel rejection) and spectrum forming. It is assembled with digital filters and localized in the first input IF stage. The development target is too radically remove adjacent channels even for robust nearby channel scenarios.

Figure 3 shows the input filter for the independence of out-of-channel influences.

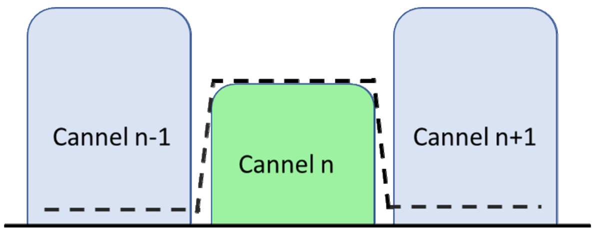

Figure 3. Adjacent channel cancellation

A SAW filter is useful to increase the adjacent channel rejection; it can accept channel bandwidths of 6, 7, and 8 MHz without requiring re-timing or precise IF spectrum shaping. It provides an adjacent channel suppression of a considerable level. This most straightforward concept requires a tuner with integrated AGC, and one 8 MHz SAW filter - irrespective of the channel bandwidth used.

4.2 LTE Filter: Technical Representation

LTE filter is a low-pass filter, to be used in DTT-reception installations. Generally, it is located at the input filtering stage of the ETF GF; this filter erases the negative influence of reflected LTE signals effectively to the input frequency of the GF

LTE filters can play a crucial role, in conditions where strong signals can disrupt, weaken, and interfere with the received television signals. This phenomenon can cause pictures to break up or making the channel impossible to obtain temporarily. Consequently, a received TV signal reaching the digital decoder does not have enough power, or it has degraded excessively, so it has no corrected.

Figure 4 shows the influence of the absence of a filter on the reception image.

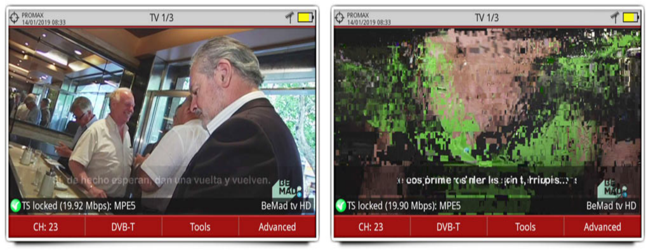

Figure 4. A full picture (left) picture with visual artifacts (right)

The degeneration and deterioration of the image quality created by the absence of the proposed filtering are not recoverable because the error correction code is not able to recover the original information. LTE filter is destined to completely removed interference by belligerently clamping down on radio signals outside of the selected channel TV broadcast band.

Consequently, the LTE filter is the more robust fight against echoes, and it enhances over the air signals by filtering out mobile signal interference that can provoke intermittent TV signal interruption conjoining weak signals.

Furthermore, the ETF GF can remove any echo caused by the coupling between the broadcasting and receiving antenna. More precisely, it can also correct the deformations of the GF input signal amplitude, provides an excellent combination of LTE, and SAW filtering to cancel echoes and straighten the input signal influenced by adjacent channels.

5 Results and Discussion

It is assuming that the received field strength of the service area network is about 60 dBμV/m. The maximum output power of an in-band gap-filler is only 35 mW (assumptions: channel 24, receive antenna gain 16 dB, transmitting antenna gain 10 dB). According to ITU-R Rec. 370-7 propagation curves, this allows extending the service into a spotted area of about 25 km.

The simulation results have been conducted mainly to evaluate the MER performances of the proposed GF scheme with a SAW and LTE filters over a Rician multipath fading channel. The Tx antenna should not have a very open radiation diagram. Ideally, the main lobe has 90° to 180°.

5.1 Performance Evaluation: Adjacent Channel Interference Cancellation

The ETF GF offers an excellent combination of analog and digital filtering. It selects the suitable input signal by canceling interference from the influences of adjacent channels.

This filter operates by converting electrical energy into acoustic or mechanical energy on a piezoelectric material. Among its particularities, it is to keep the high and stable level of the input signal without the risk of affecting the components of the signal processing chain.

According to the level of the actual input signal, the ETF GF offers a level significant of adjacent channel suppression, which leads to levels considerably lower of neighbor's level. Figure five, an adjacent channel of the input signal.

Figure 5 needs excessive filtering to eliminate the adjacent channel effectively.

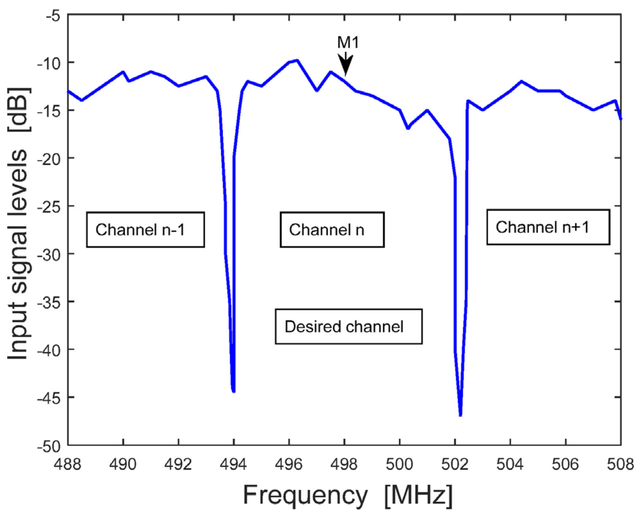

Figure 5. The adjacent channel of the input signal spectrum

Figure 6 shows the effectiveness of EFT in suppressing the adjacent channels on either side of the desired channel to be rebroadcast.

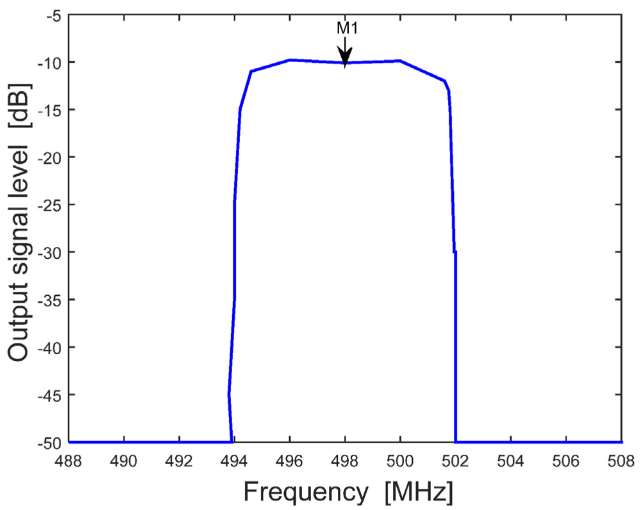

Figure 6. Output signal spectrum: adjacent channel suppression

The result in Figure 5 shows that the LTE filter included in EFT GF confronts interference by aggressively fighting against radio signals outside of the TV broadcast band.

The EFT GF graphs, of the input-output signal selection, are shown in Figure 7 and Figure 8, respectively. The Figure 7and Figure 8 below show the input/output signal response from an antenna with and without an EFT GF.

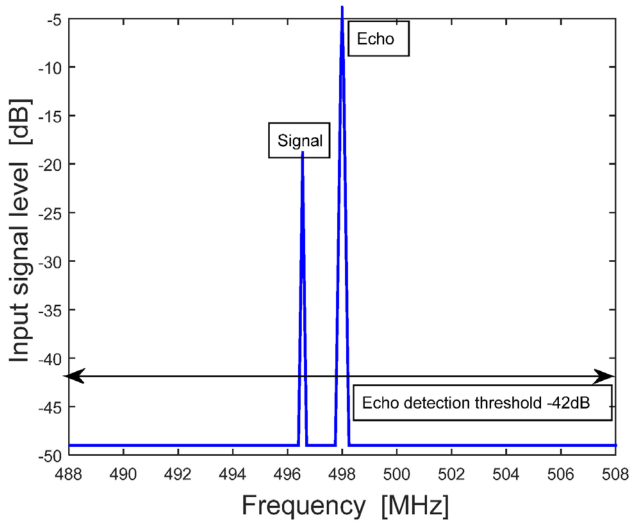

Figure 7. Input signal spectrum without echo canceller

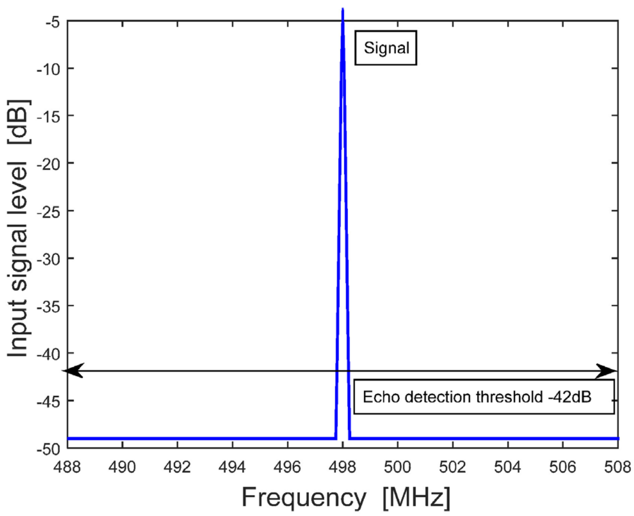

Figure 8. Output signal spectrum with cancellation echo

The EFT GF has strong signals above the 498MHz top of the broadcast TV band. Still, with a filter, those signals are significantly reduced so they will not interfere with TV reception.

5.2 Comparison Between the Proposed GF with the Other Existing Techniques

To further evaluate the performance of the proposal, we need to compare it to another Echo Canceller technique that we had previously mentioned in the first Section.

Figure 9 presents the comparison of MER for a DVB-T2 signal obtained by the simulation results of several existing techniques.

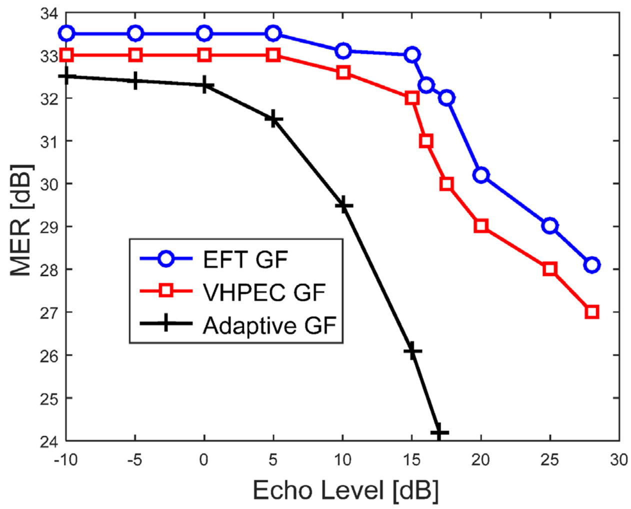

Figure 9. MER vs. Echo Level

It observed that the MER of the proposed technique EFT GF is better than the MER of VHPEC GF and Adaptive GF; it outperforms VHPEC GF and Adaptive GF by 2dB and 7dB, respectively.

In networks with a high number of gap fillers, EFT GF intelligently adapts its echo cancellation settings in changing echo situations, continuously and in real-time. This feature allowed it to provide significantly better signal quality for both changing echo characteristics as well as Doppler echo scenarios.

Figure 10 shows a comparison of the MER performance of the tree echoes cancellation techniques VHPEC GF, adaptive GF, and EFT GF.

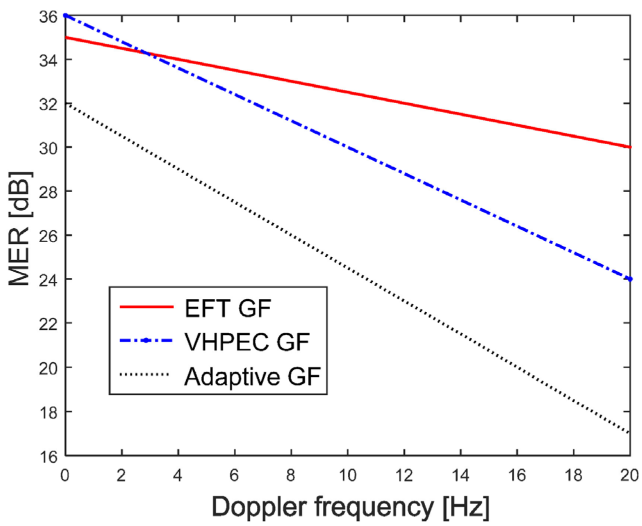

Figure 10. MER vs. Doppler frequency

In Figure 10, the proposed GapFiller not only cancels very high echo levels but also provides a secure Doppler echo cancellation and the ability to handle multiple echoes. Furthermore, it always focuses on the highly reliable operation as well as on excellent signal quality (MER), which are both of the utmost importance for network operators.

From Figure 9 and Figure 10, it can be observed that the MER performance of the proposed GF is better than VHPEC GF and Adaptive GF. We also note that the SAW filter and LTE filter can improve the robustness of the constellation, and interferences that lead to a better average. Therefore, a higher MER value promotes a wide broad coverage area.

In Figure 11 and Figure 12, we show the comparison simulation results, MER, and receive signal levels. These results apply to different GF techniques obtained in five-echo cancellation, namely VHPEC GF, standard GF (SGF), finite impulse response (FIR) filter, GF, adaptive GF, and ours GF, an Efficient Filtering Technique of Gap Filler EFT GF.

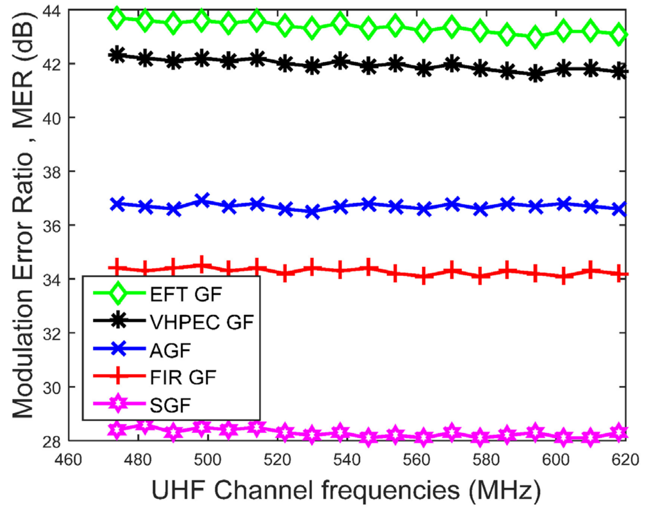

Figure 11. MER vs. UHF channel frequencies Mhz

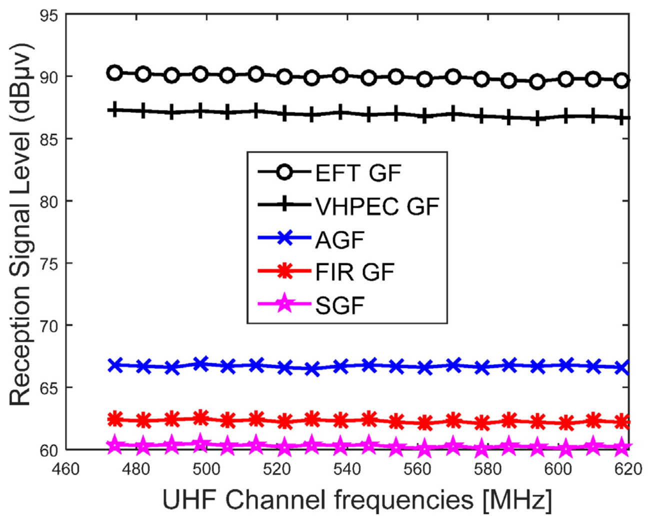

Figure 12. Reception signal level vs. UHF channel frequencies Mhz

In Figure 11 and Figure 12, the EFT GF provides MER values well above any alternative GF. Also, simulation results show that the MER and receive signal levels quality obtained by the EFT GF technique is much better than that obtained by VHPEC GF, SGF, FIR filter GF, and AGF.

5.3 General Analysis and Discussion

Table 1 summarizes the comparison between the different existing techniques obtained by five different Echo Cancellation techniques.

Table 1. Comparison of the proposed GF with other GF technique

Echo Cancellation Techniques	MER dB	Echo levels dB	Signal quality dBμv
SGF	*28.5*	*-10*	*61*
FIR GF	*34.5*	*-16*	*63*
AGF	36.9	-18	67
VHPEC GF	42.2	-22	85
EFT GF (proposed Technique)	43.4	-25	90

The summary of the analysis results Table 1 illustrates that in five scenarios, the proposed GF outperforms the existing techniques. The proposed GF surpass VHPEC GF, standard GF(SGF), finite impulse response (FIR) filter (FIR GF)), GF and adaptive GF (AGF) techniques by 7%, 39 %, 21 %, and 18 % respectively, this outperformance is also characterized by:

- Maximizing received signal quality: better than 90 dBμv levels,
- MER is better than 43dB and a lower incidence of multipath.
- Less coupling between the TX and RX antennas: Echo Level always less than -25 dB.
- Can suppress high feedback echo levels

The proposed GF can delete any multipath, and even Doppler echo. It can also be used for various kinds of coverage for the weak signal area.

This proposed GF is also designed to be used in multi-standards such as DVB-T/T2, Integrated Services Digital Broadcasting-Terrestrial (ISDB-T), Digital Terrestrial Multimedia Broadcast (DTMB), Advanced Television Systems Committee (ATSC), and ATSC-MH (mobile/handheld). It can also be used for filtering out mobile LTE signal interference (3G and 4G).

The proposed technique of Gap Filler is suitably rebroadcasting for SFN applications. It provides an excellent echo cancellation mechanism and focuses on the best signal quality in any echo scenario. Furthermore, it can be used for any of the TV technologies (ATSC, Media Forward Link Only (MediaFLO), and DVB-T/H) as well as the Chinese standards DTMB and CMMB. There is adaptability concerning the RF band (VHF/UHF) and the spectrum slot (6 MHz or 8 MHz). This proposed technique can also be employed for filtering out mobile LTE signal interference (3G and 4G).

6 Conclusions

In this paper, the efficient filtering technique of the Gap Filler EFT GF system is proposed, including LTE filter and SAW filter. This approach is considered as a critical technique to solve the echo and interference problem in the SFN environment. Also, it can preferably provide a complete coverage solution, in SFN, with echo cancellation, it cancels feedback between the broadcasting and receiving antennas. The proposed GF scheme is proposed to cover shadow zones canceling echoes with no self-interference from adjacent transmitters for DTT in SFN. Also, these GFs able to retransmit the RF signal under the most challenging echo and multipath propagation conditions removing high feedback echo levels. The PGF gives an excellent MER and can even remove the Doppler Effect. In our future works, we will employ these areas as a beginning point for strengthening information protection, such as the new error-correcting code for the next DTT generation in SFN.

Acknowledgments

The author would like to acknowledge the moral and financial efforts of Dr. Wafaa Roky.

References

[1] H. Hamazumi, K. Imamura, N. Iai, K. Shibuya, M. Sasaki, A Study of a Loop Interference Canceller for the Relay Stations in an SFN for Digital Terrestrial Broadcasting, *IEEE. Global Telecommunications Conference (GLOBECOM'00)*, San Francisco, USA, 2000, pp. 167-171.

[2] M. Lanza, A. L. Gutiérrez, I. Barriuso, J. R. Pérez, M. Domingo, L. Valle, J. Basterrechea, J. Morgade, P. Angueira, Coverage Optimization in Single Frequency Networks Using Simulated Annealing, *IEEE International Symposium on Antennas and Propagation (APSURSI)*, Spokane, USA, 2011, pp. 2789- 2792.

[3] A. Mattsson, Single Frequency Networks in DTV, *IEEE Transactions on Broadcasting*, Vol. 51, No.4, pp. 413-422, December, 2005.

[4] S. S. Das, F. H. P. Fitzek, E. D. Carvalho, R. Prasad, Variable Guard Interval OFDM in Presence of Carrier Frequency Offset, *IEEE Global Telecommunication Conference(GLOBECOM)*, MO, USA, 2005, pp. 2937-2941.

[5] ETSI, ETS 300 744, Digital Video Broadcasting (DVB); Framing Structure, *Channel Coding and Modulation for Digital Terrestrial Television (DVB-T)*, March, 1997.

[6] H. C. Wu, Analysis and Characterization of Intercarrier and Interblock Interferences for Wireless Mobile OFDM Systems, *IEEE Transactions on Broadcasting*, Vol. 52, No. 2, pp. 203-210, June, 2006.

[7] M. G. Lozano, Maria A. Lema, S. Ruiz, F. Minerva, Metaheuristic Procedure to Optimize Transmission Delays in DVB-T Single Frequency Networks, *IEEE Transactions on Broadcasting*, Vol. 57, No. 4, pp. 876-887, December, 2011.

[8] V. Savaux, M. Djoko-Kouam, A. Skrzypczak, Study of

Cyclic Delay Diversity for Single Frequency Network Using DRM Standard, European Wireless, *19th European Wireless Conference*, Guildford, UK, 2013, pp. 1-6.

[9] M. Lanza, Á. L. Gutiérrez, J. R. Pérez, J. Morgade, M. Domingo, L. Valle, P. Angueira, J. Basterrechea, Coverage Optimization and Power Reduction in SFN Using Simulated Annealing, *IEEE Transactions on Broadcasting*, Vol. 60, No. 3, pp. 474-485, September, 2014

[10] J.-D. Kim, Y.-S. Byun, A New Inter-Carrier Interference Cancellation Using CP-ICA Scheme in OFDM Systems, *IEEE 65th Vehicular Technology Conference - VTC2007-Spring*, Dublin, Ireland, 2007, pp. 2369- 2373.

[11] E. M. Ar Reyouchi, K. Ghoumid, K. Amezian, O. Mrabet, MIMO-OFDM Coded for Digital Terrestrial Television Broadcasting Systems, *International Journal of Electrical, Computer, Energetic, Electronic and Communication Engineering*, Vol. 7, No. 4, pp. 434- 438, April, 2013.

[12] E. M. Ar Reyouchi, K. Ghoumid, K. Amezian, O. Mrabet, The Powerful Alamouti Code in MIMO-OFDM Improvement for the Next Generation of Terrestrial Television Broadcasting Systems, *International Journal of Engineering & Technology IJET-IJENS*, Vol. 14, No. 1, pp. 33-42, January, 2014.

[13] X. Hou, C. Yang, Feedback Overhead Analysis for Base Station Cooperative Transmission, *IEEE Transactions on Wireless Communications*, Vol. 15, No. 7, pp. 4491-4504, July, 2016.

[14] K. M. Nasr, J. P. Cosmas, M. Bard, J. Gledhill, Performance of an Echo Canceller and Channel Estimator for On-Channel Repeaters in DVB-T/H Networks, *IEEE Transactions on Broadcasting*, Vol. 53, No. 3, pp. 609-618, September, 2007.

[15] J. K. Hong, Y. W. Suh, J. Y. Choi, J. S. Seo, Echo Canceller for On-Channel Repeaters in T-DMB System, *10th International Conference on Advanced Communication Technology*, Gangwon-Do, 2008, pp. 1735-1738.

[16] F. Lindqvist, A. Fertner, Frequency Domain Echo Canceller for DMT-Based Systems, *IEEE Signal Processing Letters*, Vol. 18, No. 12, pp. 713-716, December, 2011.

[17] E. M. Ar-Reyouchi, Y. Lamrani, K. Ghoumid, S. Rattal, Very High-Performance Echo Canceller for Digital Terrestrial Television in Single Frequency Network, *International Journal of Advanced Computer Science and Applications (IJACSA)*, Vol.11, No. 2, February, 2020.

[18] G. Tong, L. Mei, N. Xiong, C. Wu, An Improved Filtering Method Applied in Digital Mobile Terminal for Images Getting from Wireless Network Remote Transmission, *Journal of Internet Technology*, Vol. 19, No. 3, pp. 641-648, May, 2018.

[19] S. Zahoor, S. Naseem, Design and Implementation of an Efficient FIR Digital Filter, *Cogent Engineering*, Vol. 4, No. 1, August, 2017.

[20] I. Maslouhi, E. M. Ar-reyouchi, K. Ghoumid, K. Baibai, Analysis of End-to-End Packet Delay for Internet of Things in Wireless Communications, *International Journal of Advanced Computer Science and Applications(IJACSA)*, Vol. 9 No. 9, pp. 338-343, October, 2018.

[21] A. Sharif, J. Ping Li, M. A. Saleem, T. Saba, R. Kumar, Efficient Hybrid Clustering Scheme for Data Delivery Using Internet of Things Enabled Vehicular Ad Hoc Networks in Smart City Traffic Congestion, *Journal of Internet Technology*, Vol. 21, No. 1, pp. 149-157, January, 2020.

[22] C. Lu, F. Wen, Geographic Information System Query Optimisation Algorithm Based on Redundant Data Deletion and Filtering Technology, *International Journal of Internet Protocol Technology (IJIPT)*, Vol. 11, No. 4, January, 2018.

[23] J. Lima Pinto, I. Darwazeh, Phase Distortion and Error Vector Magnitude for 8-PSK Systems, *Proceedings of London Communications Symposium*, LCS, London, U.K., 2000, pp. 37-40.

[24] E. M. Ar-Reyouchi, I. Maslouhi, K. Ghoumid, A New Fast Polling Algorithm in Wireless Mesh Network for Narrowband Internet of Things, *International Journal of Telecommunication Systems*, Vol. 74, No. 3, pp. 405-410, July, 2020. Doi: 10.1007/s11235-020-00671-z.

[25] C. Rocha, C. Akamine, G. Bedicks, E. L. Horta, G. Stolfi, Adaptive Gap Filler for Digital Terrestrial Television, *IEEE International Symposium on Broadband Multimedia Systems and Broadcasting*, Beijing, China, 2014, pp. 1-6.

[26] M. M. Wang, Dynamic Gain Management for On-Channel Repeaters, *IEEE Transactions on Broadcasting*, Vol. 59, No. 4, pp. 685-692, December, 2013.

[27] M. M. Sondhi, The History of Echo Cancellation, *IEEE Signal Processing Magazine*, Vol. 23, No. 5, pp. 95-102, September, 2006.

[28] F. Ling, Achievable Performance and Limiting Factors of Echo Cancellation in Wireless Communications, *Information Theory and Applications Workshop (ITA)*, San Diego, USA, 2014, pp.1-8.

[29] ETSI, European Standard. Digital Video Broadcasting (DVB), Framing Structure, Channel Coding and Modulation for DTT, *ETSI EN 300 744 V1.4.1*, January, 2001.

[30] Y. Wang, Z. Chen, K. Gong, MER Performance Analysis of M-QAM-OFDM with Wiener Phase Noise, *International Conference on Microwave and Millimeter Wave Technology*, Builin, China, 2007, pp. 1-4.

[31] E. M. Ar-Reyouchi, Optimisation des performances des réseaux de communications sans fil: Performances des réseaux de communications sans fil pour la télégestion des stations de la Télédiffusion TV/FM, *Presses Académiques Francophones (Paf)*, June, 2017.

[32] E. M. Ar-Reyouchi, K. Ghoumid, Technical Accuracy Based on Efficiency Algorithm for Measuring Standing Wave Ratio in Wireless Sensor Network, *International Journal on Communications Antenna and Propagation (IRECAP)*, Vol. 9, No. 2, pp. 137-143, April, 2019.

Biography

El Miloud Ar-Reyouchi received his Ph.D. degree in Telecommunication and Computer Engineering from Abdelmalek Essaadi University Tetouan Morocco. Now, he is the service head of broadcasting TV/FM at SNRT. He also is with ETS computer engineering, Madrid, Spain. His current research topics cover wireless Network Protocols, Algorithms, and Broadcasting Science.