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Equalisation digital on-channel repeater with a feedback interference canceller for the advanced television systems committee terrestrial digital television system

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Abstract: In this study, the authors propose a novel equalisation digital on-channel repeater (EDOCR) with a feedback interference canceller (FIC) for a single frequency network of the advanced television systems committee terrestrial digital television system. The proposed EDOCR with an FIC not only has high output power by the cancellation of feedback signals caused by insufficient antenna isolation through the FIC, but also shows better quality of output signals than conventional digital on-channel repeaters (DOCRs) by removing multipath signals existing between the main transmitter and DOCR, as well as residual feedback signals through an equaliser. Computer simulation results are provided to demonstrate the superior performance of the proposed EDOCR with an FIC.

1 Introduction

Terrestrial television broadcasters generally operate transmitters and translators according to the geographical locations of their coverage areas. In both analogue and digital television broadcasting systems, multiple frequency networks (MFNs), where different channels are assigned to each transmitter and translator, have been used to cover service areas. However, the use of MFNs is not very efficient in terms of using frequency resources since each transmitter and translator should use different channels in an MFN configuration, unless the distance between two coverage areas is sufficiently large.

Therefore, single frequency networks (SFNs), where multiple transmitters and repeaters operate at the same frequency, are desirable for efficient frequency use. Particularly in recent years, which have seen the transition from analogue-to-digital broadcasting, the need for SFNs has been unavoidable because of a lack of frequencies required for additional transmitters and repeaters. SFNs provide not only high signal-to-noise ratios (SNRs), but also mobile digital television (DTV) services [1–3]. Recently, SFNs have been considered for the terrestrial advanced television system committee (ATSC) DTV services because of the performance improvement of DTV receivers, which are able to remove strong multipath signals with long time delays [4]. In the ATSC 8-VSB system, SFNs can be implemented with distributed transmitters (DTxTs) that use the same frequency among a number of transmitters through a global positioning system (GPS), or with digital on-channel repeaters (DOCRs) that use the same frequency between transmitters and repeaters [5–7]. In the ATSC SFN, whereas the DTxTs can transmit a high-quality signal with high power, the distance between the transmitters can be restricted by the limited equalisation range of receivers, and the cost for their setup and maintenance is relatively high. For DOCRs, their installation and maintenance can be cost-effectively achieved; however, the transmitting power is limited by the feedback signals created by insufficient antenna isolation, and thus the quality of a transmitted signal may not be secured.

Complementary to existing DOCRs for ATSC DTV service, an equalisation DOCR (EDOCR) has been proposed [8–10]. The EDOCR provides a high-quality transmitting signal with high power because of the rejection capability of feedback signals caused by insufficient antenna isolation and multipath signals existing between a main transmitter and the DOCR. However, when the electric field strength of feedback signals is higher than that of an input signal transmitted from a main transmitter, the equaliser in the EDOCR cannot remove the feedback signals, thereby causing an EDOCR malfunction. Owing to the EDOCR's limited ability to reject the feedback signals, it has low applicability in most repeating facilities and its use requires a great deal of investment.

Separately, the DOCR with a feedback interference canceller (FIC) for OFDM-based broadcasting system has been studied for recent decade [11–14]. The DOCR with the FIC can transmit a high-power signal because of the feedback signal rejection capability of the FIC, which is originally based on echo cancelling technology, although the electric field strength of feedback signals is higher than that of the input signal transmitted from the main transmitter. However, it still cannot remove multipath signals existing between a main transmitter and the DOCR although feedback signals can be rejected.

To improve the rejection capability of feedback signals in a conventional EDOCR, this paper proposes a novel EDOCR with an FIC and analyses its performance through computer simulations. This paper is organised as follows. In Sections 2 and 3, we introduce the conventional EDOCR and the DOCR with FIC, respectively. In Section 4, we then propose an EDOCR with the FIC to overcome certain disadvantages of the conventional DOCRs. In Section 5, the proposed EDOCR with the FIC is analysed through computer simulations. Finally, some conclusions are drawn in Section 6.

2 Equalisation DOCR

As shown in Fig. 1, DOCRs are installed to extend service coverage and fill gaps in areas where broadcasting signals cannot reach, such as inside tunnels, basements and shielded areas, as well as in areas where transmitters cannot be installed because of a distance limitation or economical inefficiency. Conventional DOCRs, such as the radio frequency (RF) DOCR and intermediate frequency (IF) processing DOCR, maintain constant synchronisation between receiving and transmitting signals, and have relatively short processing delays because of their simple structure. However, because of insufficient isolation between receiving and transmitting antennas, which cannot remove feedback signals, RF and IF DOCRs should transmit a low-power signal. The qualities of the transmitting signals are also low since they do not have the capability of multipath rejection. Complementary to the conventional RF and IF processing DOCRs, the EDOCR has been proposed, the configuration of which is shown in Fig. 2. An EDOCR consists of a receiving antenna, pre-selector, low-noise amplifier (LNA), frequency down converter, demodulator, equaliser, transmitter identification (TxID) inserter, modulator, frequency up-converter, high-power amplifier (HPA), channel filter and transmitting antenna. The EDOCR has the following characteristics:

- Since an EDOCR does not use forward error correction (FEC) decoding and encoding, it does not have the ambiguity problem in which the DOCR output symbol stream differs from its input symbol stream.

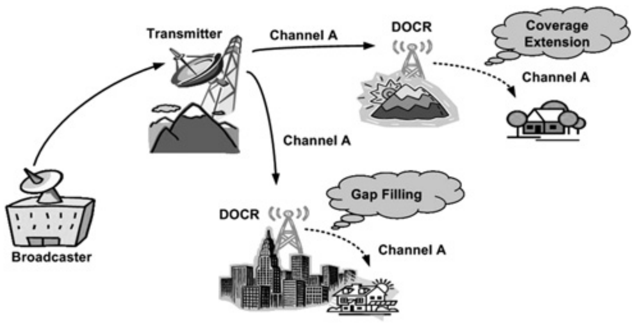

Fig. 1 *Concept diagram of a DOCR*

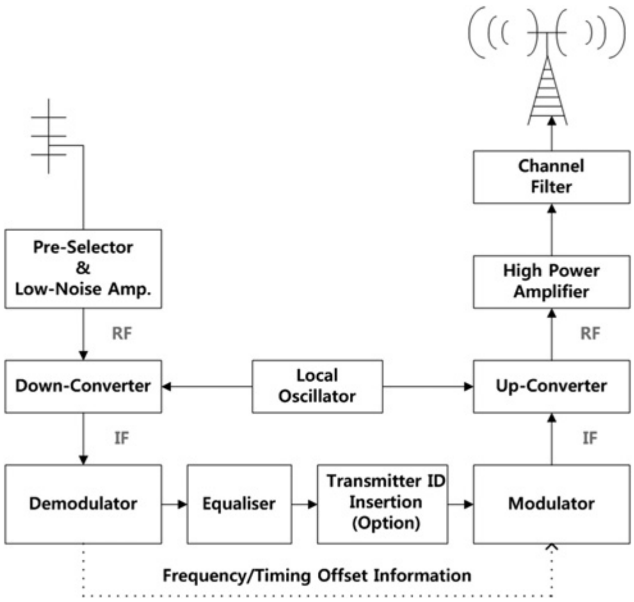

Fig. 2 *Structure of an EDOCR*

- An EDOCR has good selectivity of received signals because of its utilising a matched filter in the demodulation. That is, it is capable of rejecting adjacent channels.
- An EDOCR uses a decision-directed (DD) decision feedback equaliser (DFE), which consists of a feed-forward filter, feed-back filter and an intelligent slicer (IS) consisting of a trellis decoder with a trace back depth (TBD) of 1 [15]. Fig. 3 shows the structure of a DD-DFE. A DD-DFE is able to remove noise and multipath signals caused by signal paths between the main transmitter and EDOCR, and thus the quality of the output signal is better than that of the input signal. Also, since the equaliser rejects feedback signals because of low isolation between the transmitting and receiving antennas, the transmitting power of an EDOCR can be increased to more than ten times higher than that of conventional DOCRs.
- Since re-modulation and pre-equalisation, an EDOCR can transmit a good quality signal that meets the spectrum mask and SNR requirements of the Federal Communications Commission (FCC).

The EDOCR involves a lot of digital signal processing, which potentially causes a long time delay between transmitted and received signals compared with the conventional RF (system delay of 0.5–1 μs) and IF processing DOCRs (system delay of 1–2 μs). However, since the EDOCR adopts a demodulation scheme, where an IS for the DFE and an equi-ripple filter for the 8-VSB pulse

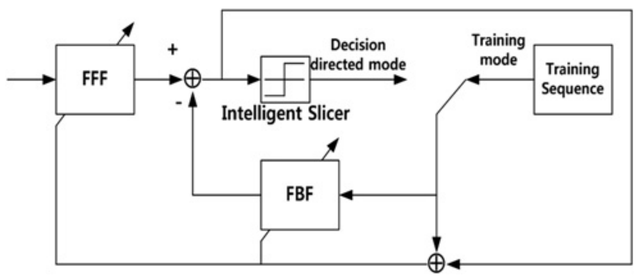

Fig. 3 *Equaliser for the EDOCR*

IET Commun., 2013, Vol. 7, Iss. 16, pp. 1769–1776
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shaping filter are included, but where no additional low-pass filters are used to remove the harmonics and no FEC decoding and encoding are performed, its signal processing time can be limited to within 5.5 μs [9, 10]. Moreover, if the electric field strength of the feedback signals is higher than that of the input signal transmitted from the main transmitter, the EDOCR cannot remove the feedback signals because of the performance limitation of the equaliser. Owing to the limited rejection capability of feedback signals, the output power of the EDOCR is strictly restricted by antenna isolation between transmitting and receiving antennas, thereby causing a low applicability in using a typical repeating facility and requiring a great deal of investment.

3 DOCR with a FIC

To overcome the output power limitation of the conventional DOCRs because of the feedback signals, a number of FICs for the DOCR, which are based on the well-known acoustic echo cancelling technology, have been studied [11–14]. There are two major conventional feedback cancellation methods for the DOCR. One is a correlation cancelling (CC) type FIC and the other is a frequency domain channel estimation (FDCE) type FIC. A CC-type FIC uses an output signal of the DOCR as a reference signal and estimates a feedback channel by correlating the reference signal with the feedback signal. An FDCE-type FIC uses a pre-determined pilot or training signal as a reference signal and estimates a feedback channel by comparing the reference signal with the feedback signal after demodulation. In general, a CC-type FIC has a simple structure. However, when correlation between the reference signal and the feedback signal is insufficient, it cannot suppress the feedback signal to the desired power level. An FDCE-type FIC has better feedback signal rejection capability than a CC-type FIC because of the channel estimation accuracy. However, its structure is more complicated because of the demodulation process to extract the pilot or training signal [14].

For a combined structure with existing DOCRs, an FDCE-type FIC cannot be adopted for a DOCR that operates in practice. Hence, a CC-type FIC is considered as an FIC for a combined structure with a DOCR, which is shown in Fig. 4. A DOCR with a CC-type FIC consists of a receiving antenna, pre-selector, LNA, first frequency down converter, CC-type FIC, frequency up-converter, HPA, channel filter and transmitting antenna. A CC-type FIC comprises a first receiving low-pass filter (LPF), first down-sampler, subtractor, decorrelation delay (DD), feedback channel estimator, complex finite impulse response (FIR) filter, transmitting LPF, up-sampler, second frequency down converter, second receiving LPF and second down-sampler. The basic operation of a CC-type FIC is as follows:

- The feedback channel estimator estimates the feedback channel caused by low isolation between transmitting and receiving antennas by correlating the second down-sampled reference signal with the output signal of the subtractor.
- The complex FIR filter generates a replicated feedback signal by filtering the second down-sampled reference signal using the estimated feedback channel.
- The subtractor removes feedback signals by subtracting the replicated feedback signal from the receiving signal of the DOCR.

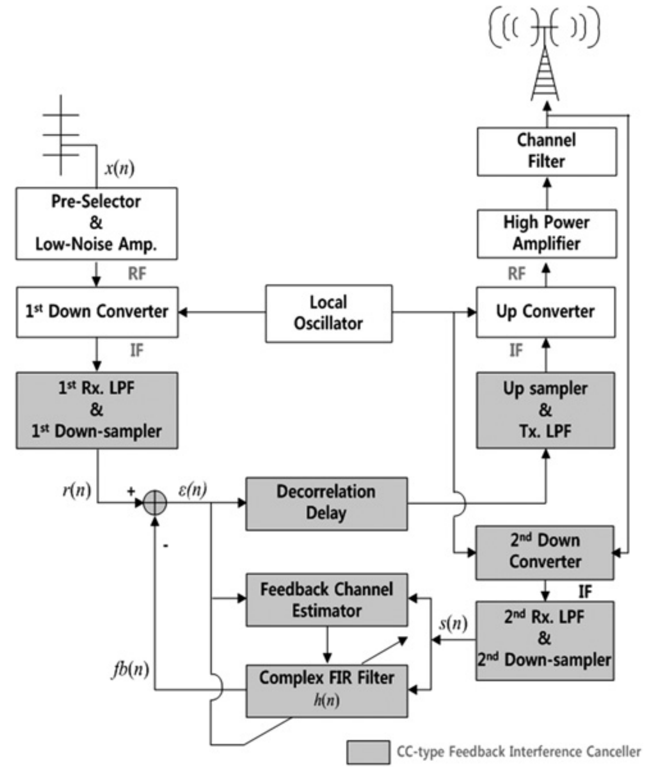

Fig. 4 *Structure of the DOCR with the CC-type FIC*

- The DD delays the output signal of the subtractor for specific time duration to estimate an accurate feedback channel.

Let the second down-sampled reference signal vector and output signal of the subtractor at time n be $\bar{s}_n = [s(n)\ s(n-1), \ldots, s(n-K+1)]^{\mathrm{T}}$ and $\varepsilon(n)$, respectively. Here, K and T are the number of complex FIR filter taps and the transpose, respectively. In addition, let the tap coefficients of the complex FIR filter at time $n-1$ be $\bar{h}_{n-1} = [h_0(n-1) h_1(n-1), \ldots, h_{K-1}(n-1)]^{\mathrm{T}}$. The objective of the FIC is to minimise the expectation of the squared magnitude of the output signal of the subtractor, $E[|\varepsilon(n)|^2]$, leaving only the signal from the main transmitter. In order to achieve this goal of the FIC, the tap coefficient at time n can be calculated based on the least-mean-square algorithm (LMS) as follows

$$\bar{h}_n = \bar{h}_{n-1} + \lambda\, \varepsilon(n)\, \bar{s}_n^* \tag{1}$$

where λ is a constant for determining the convergence speed and * is a complex conjugate. A replicated feedback signal fb(n) at time n is generated by the inner product of the second down-sampled reference signal vector $\bar{s}_n$ and the tap coefficients $\bar{h}_n$, as follows

$$\mathrm{fb}(n) = \bar{h}_n^{\mathrm{T}}\, \bar{s}_n^* \tag{2}$$

Finally, feedback signals are cancelled by subtracting the replicated feedback signal fb(n) from the first down-sampled signal $r(n)$ of the DOCR receiving part, and the output signal $\varepsilon(n)$ of the subtractor is as follows

$$\varepsilon(n) = r(n) - \mathrm{fb}(n) \tag{3}$$

The system delay of the CC-type FIC depends on the transmitting/receiving LPFs and DD. Since the correlation between the input signal transmitted from the main transmitter and the output signal of the DOCR should be minimised for an accurate feedback channel estimation, the time delays of the transmitting/receiving LPFs and DD should be as long as possible [11]. However, since the long time delays of the LPFs and DD increase the system delay of the DOCR, the lengths of the LPFs and DD are strictly restricted by the maximally permitted system delay of the DOCR.

4 EDOCR with a FIC

The proposed EDOCR with an FIC has the serially concatenated structure of the existing EDOCR and CC-type FIC as shown in Fig. 5. This serially concatenated structure makes an easy installation of the FIC to an existing EDOCR that is currently operating in practice. For stable operation of the equaliser in the existing EDOCR, carrier and timing synchronisation of the demodulator should be performed prior to the equalisation. However, if the feedback signal power is higher than the input signal power transmitted from the main transmitter, the frequency and timing synchronisation cannot be maintained. Therefore the CC-type FIC has to be located between the down-converter and the demodulator for stable synchronisation. Moreover, in order to prevent a malfunction of the equaliser because of the feedback signal, the suppressed feedback signal power should be 4 dB below the input signal transmitted from the main transmitter. This minimum feedback cancelling requirement is because of the capability of the equaliser of the existing EDOCR [8, 9].

In general, since a processing time delay of the DOCRs causes a signal from the main transmitter to act as a pre-echo in the DOCR coverage area, resulting in a performance degradation of the legacy receiver, it should be as short as possible. Considering the reception capability of legacy receivers, the maximally permitted processing delay of DOCRs for the ATSC DTV system is generally within about 10 µs. The EDOCR involves a lot of digital signal processing, which possibly causes a long time delay between transmitted and received signals compared with conventional DOCRs. Owing to the non-inclusion of FEC decoding and encoding, however, its signal processing time can be limited to within 5.5 µs [8, 9]. Since a processing delay of the EDOCR is about 5.5 µs, the time delay of the CC-type FIC should be less than 4.5 µs. To reduce the processing delay of the CC-type FIC, the DD, which has the longest time delay in the CC-type FIC, is replaced by a matched filter of the demodulator, an equaliser and a pulse-shaping filter of the re-modulator. Therefore the processing delay of the CC-type FIC is determined by the number of transmitting/receiving LPF taps. Since the transmitting LPF is used for the rejection of the mirror image after the up-sampler, it can be implemented with a small number of LPF taps. However, the receiving LPF is directly related to both the feedback cancellation performance of the CC-type FIC and the processing delay. The receiving LPF plays a role in rejecting the adjacent channel and increasing the SNR of its input signal by eliminating the noise. Therefore the receiving LPF with the tight spectral characteristic provides the better feedback cancelling performance by making the received signal be similar to the original signal as far as possible. To make the filter have a tight spectral shape, we should use a large number of receiving LPF taps, which cause a large processing delay. Since an additional processing delay should be as short as possible, hence, there is a trade-off between the processing time delay and the performance of the FIC.

In terms of the equaliser in the conventional EDOCR, the FIC causes an additional channel that distorts the input signal transmitted from the main transmitter. If the signal, which is recovered by the FIC, varies rapidly, the channel estimation in the EDOCR may be inaccurate. To prevent such performance degradation, a small variance of the recovered signal has to be maintained. The variance of the recovered signal is directly related to the value of the step sizes used in the adaptive filter update, and thus a small step size should be assigned.

The above mentioned requirements can be summarised as follows:

- The FIC has to be located between the down-converter and demodulator of the EDOCR for stable synchronisation of the demodulator and equaliser operation. It should be directly combined with the EDOCR, which is already installed in a real field, without any modifications of the existing EDOCR.
- The proposed EDOCR with an FIC should suppress a feedback signal whose power is at least 30 dB higher than that of the input signal transmitted from the main transmitter to cover a sufficiently-large area. For stable operation of the equaliser, the suppressed feedback signal power should be 4 dB below the input signal transmitted from the main transmitter.
- The processing time delay of the proposed EDOCR with an FIC should be limited to within 10 µs, and the time delay of the FIC should also be less than 4.5 µs.
- The proposed EDOCR with an FIC should minimise any performance degradation of the equaliser caused by the addition of the FIC.

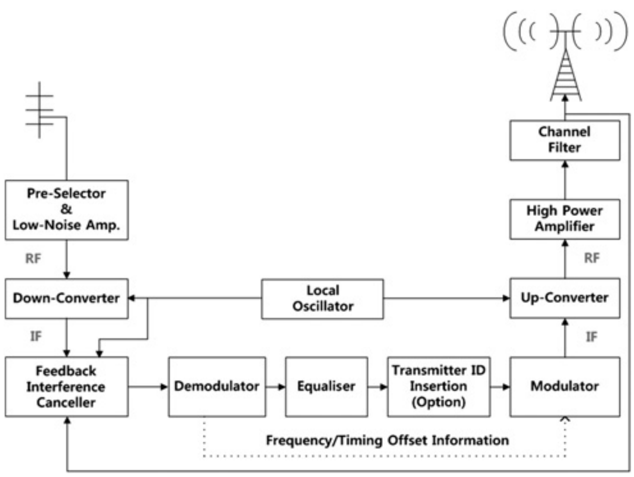

Fig. 5 *Structure of the proposed EDOCR with a CC-type FIC*

5 Computer simulation

To verify the performance of the proposed EDOCR with an FIC, we implemented the simulator shown in Fig. 6 and analysed the performance in three aspects: a spectrum analysis, FIC performance and equaliser performance. Considering the environment for the DOCR installation, the line-of-sight (LOS) from the main transmitter is generally guaranteed, thus the main channel can be modelled as Brazil channel A whose channel profiles are shown in Table 1 [16]. To analyse the maximum performance of the proposed system, we neglect the noise caused because of any analogue

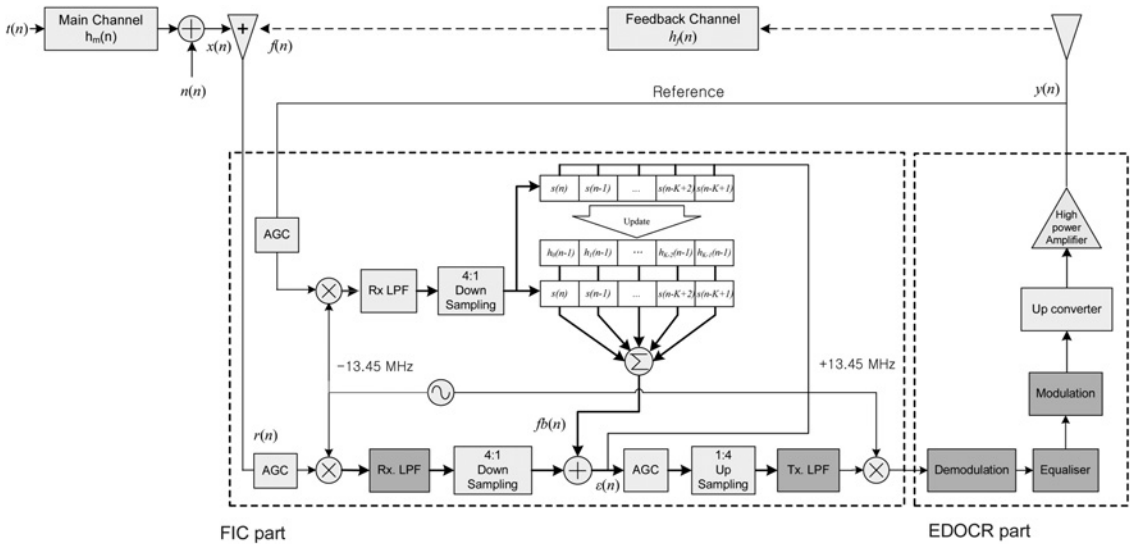

Fig. 6 *Block diagram for computer simulations*

Table 1 Channel profile of Brazil channel A

Margin	Delay, s	Amplitude, dB	Phase, deg.
Main signal	0.0	0.0	0
Post-Ghost #1	0.15	−13.8	0
Post-Ghost #2	2.22	−16.2	0
Post-Ghost #3	3.05	−14.9	0
Post-Ghost #4	5.86	−13.6	0
Post-Ghost #5	5.93	−16.4	0

device by assuming that the noise figure of each one is sufficiently small. We considered a carrier-to-noise ratio (CNR) at the receiving antenna for the quality of the main signal and the SNR degradation caused by the automatic gain control (AGC) as noise sources in the proposed system. In the case of evaluating the FIC performance, we fixed the CNR value by 30 dB considering the site of DOCR's installation. On the other hand, CNR values were varied for the verification of the equaliser's performance. The structure of an AGC circuit used in our simulation is shown in Fig. 7 [17]. We set the gain-control parameter of the feedback function in each AGC circuit to make it have the quality of a gain-controlled signal by 40 dB input SNR. As a result, the AGC produced −40 dB noise automatically relative to the power of its input signal. A feedback channel was assumed as a mild one-path channel, which has a main feedback signal, and a severe three-path channel, which has a main feedback signal and two sub-feedback signals. The main feedback signal was modelled with a power 30 dB higher than that of the input signal transmitted from the main transmitter. In addition, the main feedback signal was assumed to be delayed by 0.5 μs at the repeater output. The system delay considered in our simulations is determined by

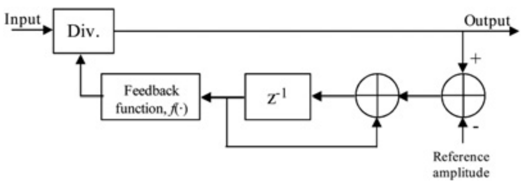

Fig. 7 *Block diagram of each AGC circuit*

five delay elements marked in Fig. 6. They are the receiving/transmitting filters in the FIC, the matched filter in the demodulator, a centre tap of an equaliser and the pulse-shaping filter in the modulator. The types and the number of taps of the last two filters in the EDOCR part are exactly the same as those of the existing EDOCR. As mentioned in Section 4, a small number of taps are enough for the transmitting filter and a large number of taps should

Table 2 Simulation parameters

Parameters	Specifications
sampling frequency	43.04 MHz
IF center frequency	13.45 MHz
channel	Brazil channel A
CNR	10 ~ 30 dB
feedback channel	one path channel (mild channel condition) three paths channel (severe channel condition)
feedback signal power	main feedback path: + 30 dB first sub-feedback path: + 20 dB (2 Hz Doppler effect) second sub-feedback path: + 10 dB (10 Hz Doppler effect)
feedback signal delay (to DOCR output)	main feedback path: 0.5 μs first sub-feedback path: 1.5 μs secong sub-feedback path: 3.0 μs
the rate of increasing HPA gain	72 ms to + 30 dB (linearly increases)
FIC Rx. LPF length	301 (delay : 3.5 μs)
FIC Tx. LPF length	41 (delay : 0.5 μs)
FIC adaptive filter length	50 (feedback signal cancelling range: 4.65 μs)
FIC step size	0.000001
matched filter length in the demodulator	61 (delay : 0.7 μs)
equalizer FFF length	40 (center tap: 5 (delay : 0.5 μs))
equalizer FBF length	192
pulse shaping filter length in the modulator	191 (delay : 2.2 μs)
feedback functions in AGCs	linear (after receiving antenna) exponential (after feedback cancellation)
system delay	FIC : 4.0 μs EDOCR : 3.4 μs (excluding A/D, D/A, pre-equaliser, and analogue parts (pre-selector, LNA, HPA and up/down converter))

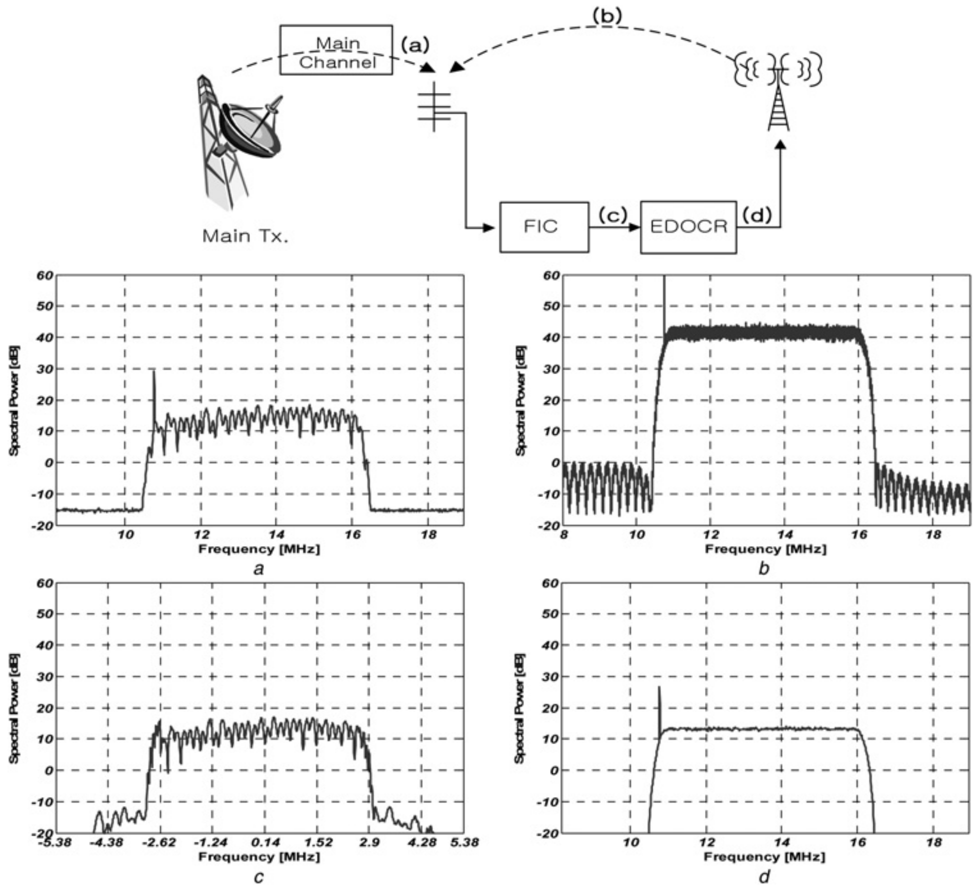

Fig. 8 *Spectrum analysis*

a Spectrum of the signal transmitted from a main transmitter
b Spectrum of feedback signal
c Spectrum of FIC output signal
d Spectrum of EDOCR output signal

be assigned for the receiving filter for better performance. In our simulation, 41 taps and 301 taps are assigned for the transmitting and receiving filters, respectively. Based on the fact that the considered filters have a half filter-length delay and the IF sampling frequency is 43.04 MHz, the delay of each filter can be calculated as presented in Table 2. A centre tap in an equaliser, which plays a role in reflecting a non-causal part of the main channel, delays the five baseband samples, eq., about 0.5 µs. Other parameters associated with the simulation, such as a sampling frequency, IF centre frequency, sub-feedback signal, various filter lengths, increasing speed of HPA gain and so forth, are summarised in Table 2.

5.1 Spectrum analysis

To evaluate the performance of the proposed EDOCR with an FIC, we first observed the spectrum analysis briefly. Figs. 8*a* and 8*b* show the spectrum of a signal distorted by Brazil channel A with 30 dB CNR and a feedback signal whose power is 30 dB higher than the signal transmitted from the main transmitter, respectively. The signal transmitted from the main transmitter is inputted into the FIC through a receiving antenna after combination with the feedback signal. Although the FIC successfully suppresses the feedback signal based on the CC algorithm, as shown in Fig. 8*c*, the FIC output signal still has distortions caused by the multipath and residual feedback signals. Since the EDOCR performs the demodulation, equalisation and re-modulation using the FIC output signal, it can transmit a clean signal as shown in Fig. 8*d*, which meets the spectrum mask and SNR requirement of the FCC. If the DOCR does not perform proper equalisation on the received signals, the multipath and residual feedback signals after FIC operation are amplified and retransmitted by the DOCR. These distortions may be combined with channel distortions between the DOCR and

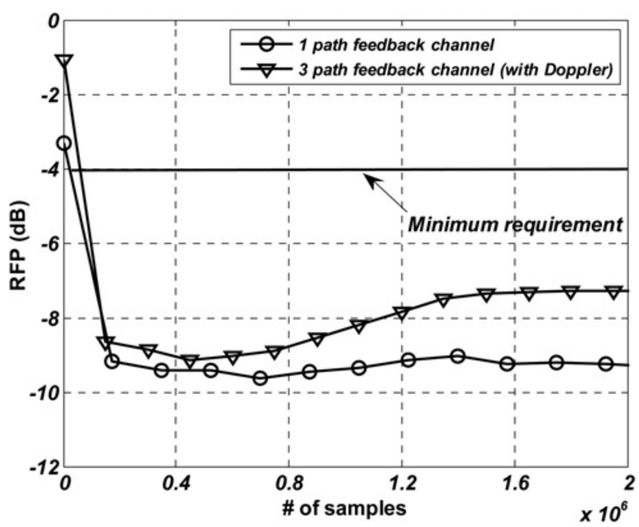

Fig. 9 *RFP curves according to the feedback channels*

IET Commun., 2013, Vol. 7, Iss. 16, pp. 1769–1776
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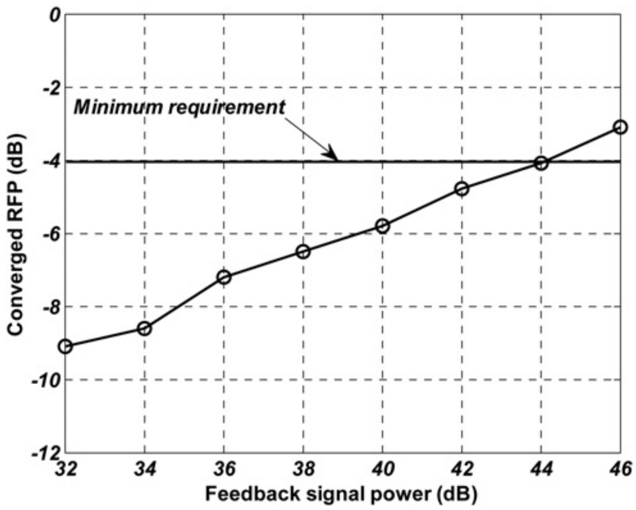

Fig. 10 *RFP curves according to the feedback powers*

legacy receivers, resulting in a performance degradation of the legacy receivers. Hence, it is crucial to deploy an equaliser within the DOCR to increase its coverage.

5.2 Performance of a FIC

The measuring index of the FIC is a residual feedback power (RFP), which means the remaining feedback signal power in the recovered signal. The RFP is defined by

$$\mathrm{RFP} = 10\log_{10}\left(\frac{E[e(n)e^*(n)]}{E[t(n)t^*(n)]}\right) \quad (4)$$

where $e(n)$ is the difference between the main input signal, $t(n)$, transmitted from the main transmitter and the recovered signal, $\varepsilon(n)$. For stable operation of the equaliser in the EDOCR, the RFP values should be less than −4 dB [7, 8]. For feedback channels, a mild one-path channel and severe three-path channel whose two sub-feedback signals have a Doppler effect were used. Fig. 9 shows the RFP performance of the FIC according to channels. Based on computer simulation results, although the RFP performance in the severe channel was worse than that in mild channel because of the Doppler effect and more feedback signals, the FIC satisfies the minimum feedback cancelling requirement of the existing EDOCR. In particular, a feedback signal power +30 dB higher than the signal transmitted from the main transmitter was suppressed by more than +37 dB in the severe channel and +39 dB in the mild channel.

To observe the maximum feedback cancelling capability of the proposed EDOCR with an FIC, the RFP performance was measured according to the feedback signal power under a mild one-path channel. Fig. 10 shows the converged RFP performance when the feedback signal power is over 30 dB more than that of the input signal transmitted from the main transmitter. Based on computer simulation results, the converged RFP was −4 dB, which is the minimum requirement for stable operation of the equaliser when the feedback signal power is 44 dB. This means that the proposed EDOCR with an FIC can suppress a feedback signal whose power is at maximum 44 dB higher than that of the input signal transmitted from the main transmitter.

5.3 Performance of an equaliser

As discussed in Section 4, an FIC implemented based on the EDOCR causes an additional time-varying channel, the equalisation performance of the proposed EDOCR is

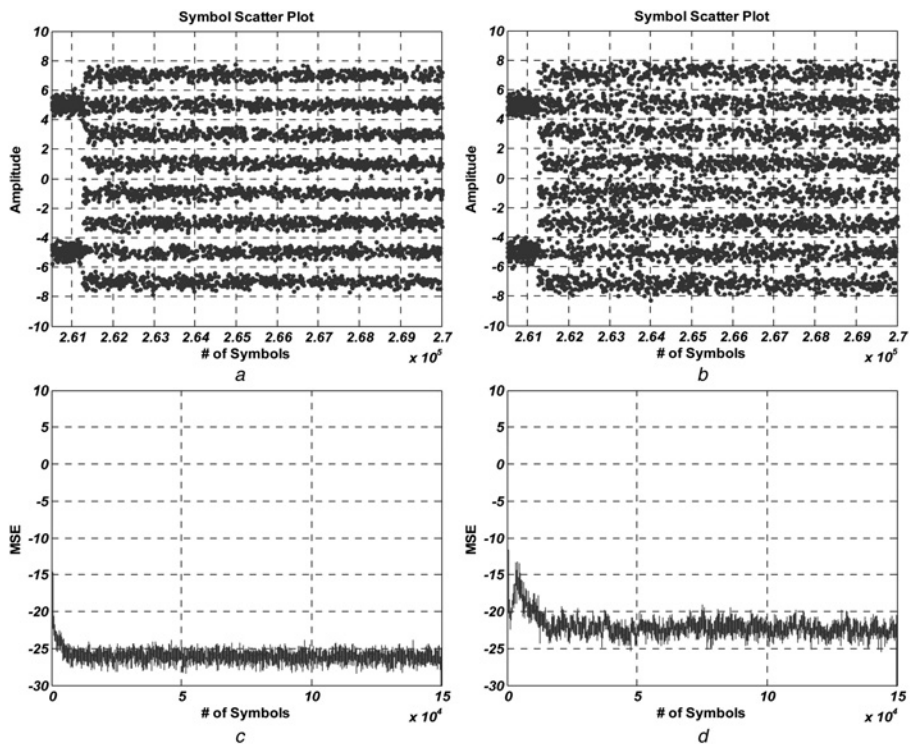

Fig. 11 *Equaliser performance of the conventional EDOCR and proposed EDOCR with an FIC*

a Symbol scatter diagram of the conventional EDOCR
b Symbol scatter diagram of the proposed EDOCR with an FIC
c MSE curve of the conventional EDOCR
d MSE curve of the proposed EDOCR with a FIC

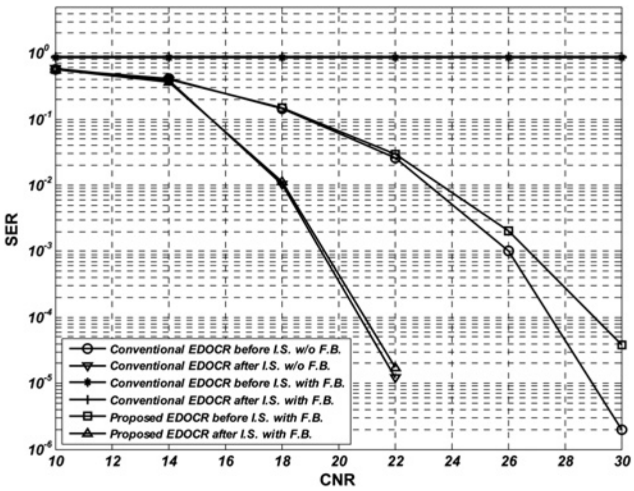

Fig. 12 *SER performance of the conventional EDOCR and proposed EDOCR with an FIC before and after the use of an IS*

deteriorated and this unavoidable degradation should be minimised. Since the equaliser of the conventional EDOCR, which uses the error-correctable IS in Fig. 3, can minimise the error propagation, the equalisation performance degradation caused by the addition of an FIC is negligible. To verify this issue, we compared the equalisation performance of the proposed EDOCR with an FIC to that of the conventional EDOCR. The channel between the main transmitter and the DOCR used Brazil channel A with a 30 dB CNR, and the feedback channel used the single mild path.

Fig. 11 shows a scatter diagram and mean-square-error (MSE) performance of the equaliser output. From Figs. 11*c* and 11*d*, the MSE performance of the proposed EDOCR with an FIC was degraded by about 3 dB than that of the conventional EDOCR without feedback channel. This performance degradation of the equaliser also showed up in aspect of symbol error rate (SER) performance.

Fig. 12 shows the SER performance of the conventional EDOCR and the proposed EDOCR with the FIC before and after the IS. SER curves denoted as the conventional EDOCR without feedback were obtained by simulations in condition of no feedback signal. Therefore they represent the target performance of the proposed EDOCR in the presence of the feedback signal. As depicted in Fig. 12, while the conventional EDOCR cannot recover the symbol distortion because of a large feedback signal, the proposed EDOCR with an FIC can compensate the symbol distortion. Although the SER performance of the proposed one before the IS is worse than that of the conventional one, the SER performance after the IS is almost the same as the target performance. This means that the IS of the conventional EDOCR can handle such performance degradation of the equaliser caused by an additional FIC. Therefore the proposed EDOCR with an FIC significantly suppressed a feedback signal caused by insufficient isolation between the transmitting and receiving antennas, and multipath signals between the main transmitter and the DOCR.

6 Conclusion

This paper proposed an EDOCR with an FIC for the SFN of the ATSC DTV system and analysed its performance through computer simulations. Owing to its simple module-designed structure, the proposed system can be implemented economically by only adding an FIC to the currently-operating EDOCR without any significant modifications of the existing EDOCR. In addition, it can also minimise the possible negative effects to legacy receivers by strictly limiting an additional system delay allowed for an FIC. The proposed system uses a CC-type FIC to cancel the feedback signals and a DD-DFE to compensate for channel distortions such as multi-path signals and residual feedback signals. Based on our computer simulation results, the proposed system not only suppresses the feedback signal whose power is 30 dB higher than that of the input signal transmitted from the main transmitter, it also removes multi-path signals such as Brazil channel A with 30 dB CNR. Therefore the proposed EDOCR with an FIC can provide much larger coverage area and high-quality re-transmitted signals, and thus can yield high performance ATSC networks with fewer frequency resources.

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