A possible method of Graceful Deployment of Digital Broadcasting in the FM-band using the DRM30 broadcasting standard

Preliminary

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Abstract

A study was performed by the undersigned on how to introduce Digital Broadcasting gracefully in a congested FM-band, comparing the performance to the typically suggested method of simulcast in the VHF-band II (FM-band) using 96 kHz DRM+ RF-bandwidth, to a method heretofore unexplored of using 20 kHz DRM30 RF-bandwidth for Single Channel Simulcast (SCS) in the FM-band.

RF-bandwidth is a precious item that should be sparingly and effectively utilized. Traditional analogue broadcasting technologies like FM and AM are uneconomical, wasteful and ineffective to use. This impose limitations and bottle-necks in frequency availability, frequency planning and in listener coverage as well as user utility.

Digital broadcasting offers benefits such as absence of distortion, noise, interference and fading, common to analogue broadcasting. In addition, Digital Broadcasting offers new content and utility for the listeners like multimedia slideshows, video and meta-data, as well as automatic station identification. In addition, Single Frequency Networks (SFN) utilizes RF-bandwidth with maximum efficiency as it offers reuse of the same frequency for a large number of transmitters. Digital broadcasting also offers audience interaction over the Internet in real-time (if online).

RF-congested areas are typically major cities, where the FM-band usually is crammed with broadcasters and the Stockholm area is no exception in this respect. According to The Swedish Post and Telecom Authority (PTS) there is practically no further FM-space available in the Stockholm area, making it difficult or impossible for new local radio or small community broadcasters to establish themselves in the FM band either as Digital Broadcasters or as conventional broadcasters in the FM-band.

A switch-off date of analogue transmissions in the FM-band is discussed but unlikely to occur in the near term, making it unattractive to hard-switch from analogue broadcasting to digital for those broadcasters that are interested to test and offer their audience new attractive technology. Thus, in order to offer a graceful migration to digital, simulcast is the only option during the transition period for the FM-band.

However, as there is typically little RF-space remaining in the FM-band it is unlikely that traditional simulcast (DRM+ together with FM) will be feasible to introduce, at least not if impairing the current frequency grid, or if not complying with the ETSI FM-spectrum mask. Thus a graceful solution is needed for the deployment of digital broadcasting in the FM-band.

Broadcasting background

AM broadcasting is the simplest technology for audio broadcasting and has been available since 1920 with regular broadcasts of dramas, comedy and other forms of entertainment like news and music. AM is prone to annoying interference and fading, and AM signal quality degrades gradually with distance and signal strength, typical to analogue modulation methods. It is believed that due to the low sound-quality of AM, listeners are abandoning this technology for better sounding alternatives.

FM broadcasting has been available in mono since the late 1930's and in stereo since the early 1960's. It has since reclaimed many listeners from the AM band and is a popular and widespread modulation format that offers good audio sound quality and fair robustness to interference in comparison to AM broadcasting. The FM band usually covers 87.5 – 108 MHz and is typically divided in 100 kHz spacing channels. FM quality degrades gradually with distance and signal strength, typical to analogue modulation methods.

Digital Audio Broadcasting (DAB) has been available since 1995 and is slowly gaining in popularity in a number of countries due to its robustness to interference and the possibility to offer high audio quality. DAB is substantially more spectrum efficient than analogue modulation techniques like FM or AM. DAB exhibits the typical "brick-wall effect", where the signal degrades rapidly when signal strength falls below a certain critical threshold. The modulation used for DAB is coded orthogonal frequency division multiplexing (COFDM), a very effective modulation method that however set very stringent demands on the transmitter due to the high crest-factor of OFDM signals. The bandwidth of one DAB multiplex is 1536 kHz wide.

A recent upgrade (2007) of the DAB standard to **DAB+** includes a substantially more effective audio coder (HE-AAC), and offers approximately twice the programme channels. DAB broadcasts in the VHF band III (174 to 230 MHz). DAB can transmit multimedia features like program-associated metadata, 5.1 surround sound, slide-shows and video etc.

Digital Radio Mondiale (DRM30) has been available since 2003 for broadcasting in the band below 30 MHz (LW, MW, SW) and is gaining in popularity in a number of countries due to its robustness to interference and the possibility to offer high audio quality over substantial coverage areas. DRM is much more spectrum efficient than analogue modulation techniques like FM or AM, and even slightly more spectrum efficient than DAB. DRM exhibits the typical "brick-wall effect", where the signal degrades rapidly when signal strength falls below a critical threshold. The modulation used for DRM is as for DAB, coded orthogonal frequency division multiplexing (COFDM), a very effective modulation method that however set very stringent demands on the transmitter due to the high crest-factor of OFDM signals.

DRM30 opens up the additional possibility to cover extremely large areas and intercontinental broadcasting using only one transmitter, eliminating annoying interference and fading common to analog intercontinental AM broadcasting.

The recent extension of Digital Radio Mondiale to DRM+, moves DRM+ into the VHF bands I – III (TV, FM and DAB bands). This new broadcasting standard has been available since 2009. DRM can transmit features like program-associated metadata, 5.1 surround sound, multimedia services like slide-shows and video etc. DRM is the only available broadcasting technology that can cover the complete RF broadcasting spectrum, from 100 kHz to 230 MHz (LW/MW/SW/VHF I/VHF II/VHF III). The bandwidth of one DRM multiplex is from 4.5 kHz to 96 kHz kHz wide, dependent on DRM mode used and thus is very spectrum efficient.

DRM and DAB can work seamlessly together and the two technologies can complement each other. Both DAB and DRM uses the acclaimed and very efficient HE-AAC codec (the undersigned initiated the SBR and PS project and thus contributed as inventor and to the success of the HE-AAC codec).

The general opinion is that DAB is better suited for national broadcasters and commercial radio broadcasters interested in covering larger geographical areas. The DAB multiplex is 1536 kHz wide, consuming substantial RF space. Thus in order to effectively utilize RF space, it is imperative to fill the DAB multiplex with a number of radio programmes (in the order of 20 per multiplex). However DAB typically asks for a comparatively large and costly infrastructure usually run by government agencies or major corporations.

DRM+ on the other hand, uses only a RF space of 96 kHz for the DRM+ multiplex, thus consuming half the space of one analogue FM channel, and can broadcast up to three radio programmes in this narrow space with FM radio quality. DRM is typically a small-scale installation requiring no more infrastructure than what is normal for a standard FM-transmitter site. Thus the DRM local radio broadcaster or community radio broadcaster typically finances his own transmitter site. However, such transmitter site can be infinitely expanded if needed, to cover multiple broadcasters and programme channels.

Thus in a future broadcast scenario, DAB+ and DRM+ could co-exist, where the advantage of each standard could be exploited to its maximum extent and up to the broadcasters needs and decisions. DAB could preferably be used for nation-wide broadcasts by government broadcasters and commercial broadcasters. DRM could advantageously be used for private local broadcasters and small community radio broadcasters.

Stockholm broadcast scenario

Below is a spectrum plot of the Stockholm FM band covering 88 – 108 MHz, measured at the undersigned's location in Stocksund, 6.5 km from Stockholm city centre. The red line represents the proposed test frequency for the Stockholm DRM+ Field Trials at 102.4 MHz. Two transmitters are in the vicinity of this frequency: (1) Radio-1 at 101.9 MHz and 3.9 kW ERP and (2) Swedish Radio P4 at 103.3 MHz and 60.3 kW ERP. In the larger Stockholm area there are 4 high-power broadcasts, 15 medium-power broadcasts and 23 low-power community radio broadcasts. Thus approx. 42 broadcasts in all, (at an average FM-band spectrum density of one broadcast per 0.490 MHz).

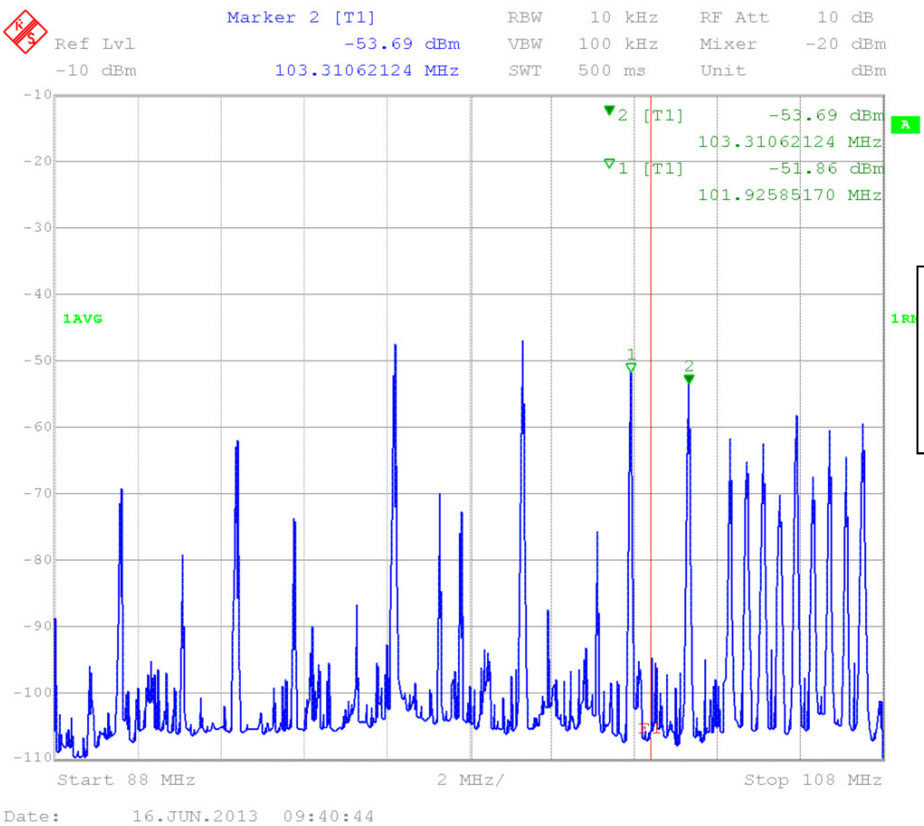

Fig. 1

A spectrum plot of the Stockholm VHF band II (FM)

FM broadcasting

Frequency modulation (FM) conveys information by varying a carrier in frequency, where the instantaneous frequency is proportional of the instantaneous value of the input signal amplitude. The FM signal has constant power. The FM carrier frequency deviation is typically limited to +-75 kHz by legal regulatory bodies. An interesting phenomenon of FM demodulation is its comparatively wide and sensitive “capture effect” making FM tolerant to inaccurate frequency setting of the receiver, or low-quality drifting receivers. This effect is utilized further below.

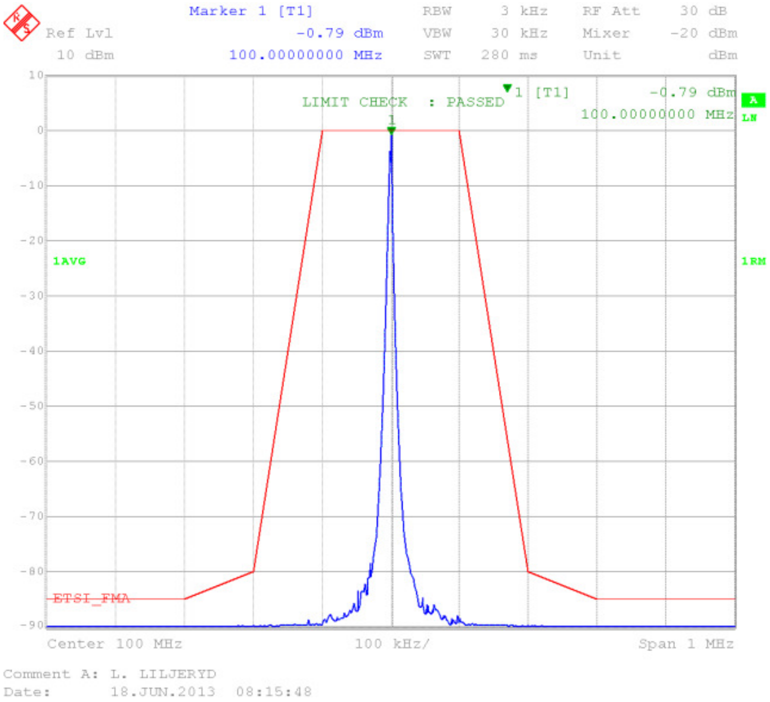

Fig. 2

An un-modulated FM carrier spectrum

The above diagram shows the pure un-modulated FM carrier as level reference.

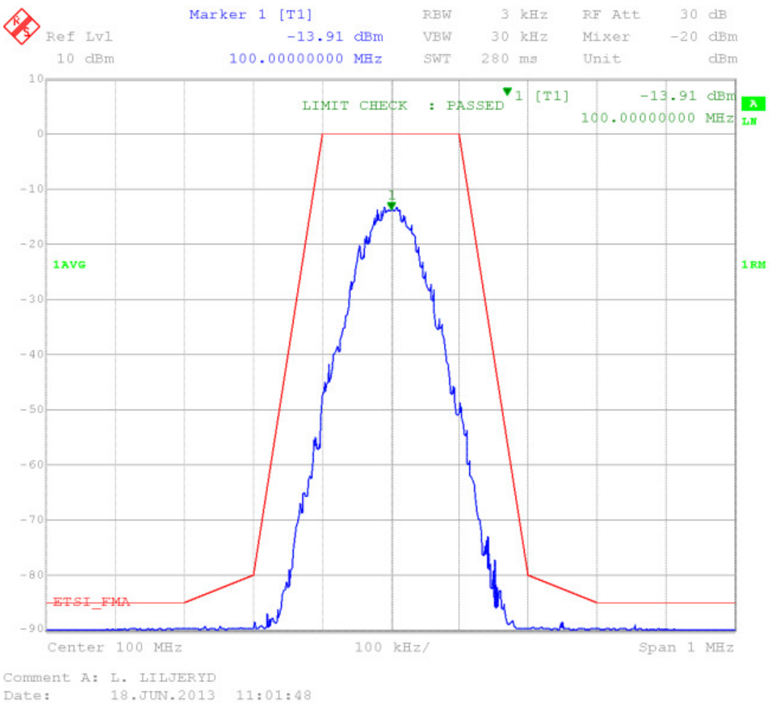

Fig. 3

A typical modulated FM carrier spectrum

The above diagram shows a modulated FM-signal (pink-noise input). In a typical FM-transmission, the emitted signal has to comply with the ETSI FM spectrum mask (red). This implies that it is illegal to over-modulate the transmitter (more than +- 75 kHz deviation), produce obtrusive signals, harmonics, or residuals outside of the spectrum mask limit.

DRM+ and DAB

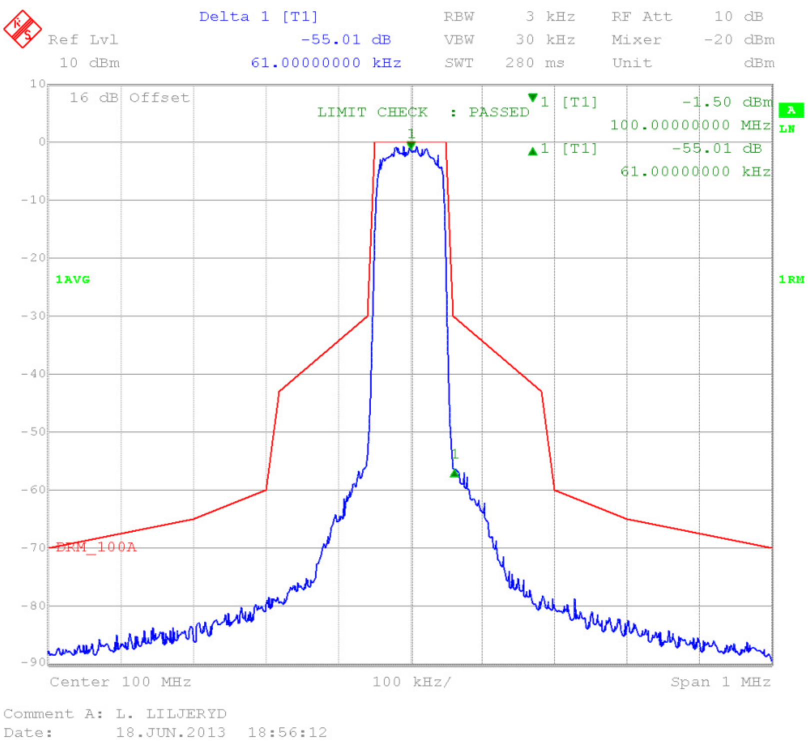

Fig. 4

A typical DRM+ OFDM carrier spectrum

The above applies also to DRM+ transmissions, where the emitted DRM+ signal has to comply with the ETSI DRM spectrum mask. The above spectrum shows the DRM+ signal spectrum. The shoulder distance is in this case around -55 dBc.

DRM+ occupies a RF-bandwidth of 96 kHz.

DAB and DAB+ occupy a RF-bandwidth of 1536 kHz.

DRM+ and FM simulcast

Certain DRM+ and FM parameter settings has been established and evaluated by a number of authors in order to create efficient simulcast broadcasting of combined FM and DRM+ signals in the VHF band II (FM-band). Usually the DRM+ signal is placed at a delta-frequency of 150 kHz (or sometimes 200 kHz) from the FM-carrier centre, where the DRM+ signal, in order to protect the FM-receiver, has to have a approx. 23 dBr (or >20 dBr) lower signal power than the FM signal.

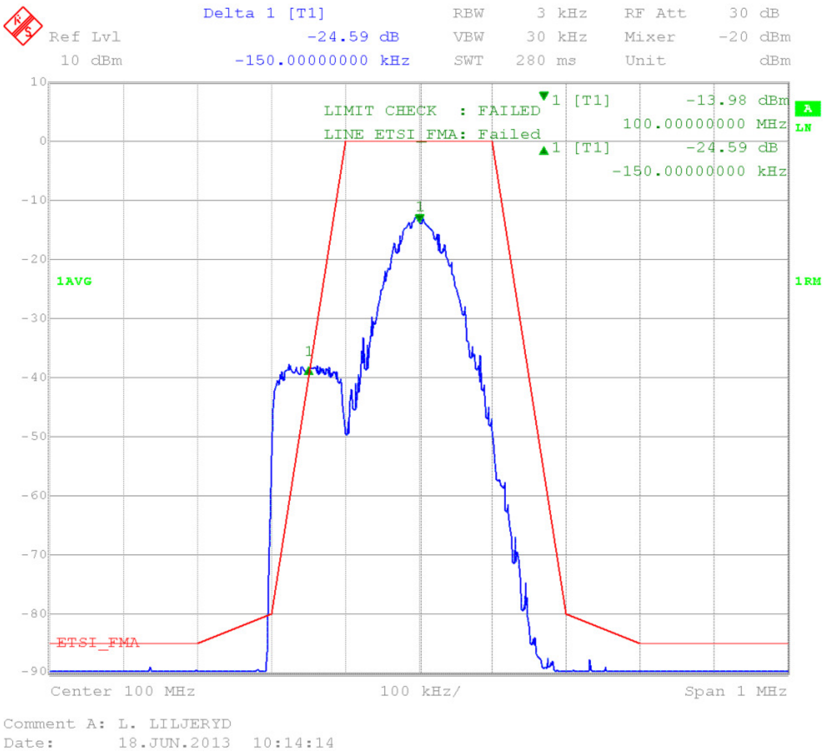

Fig. 5, **Simulcast alternative 1**

A Typical simulcast spectrum containing a DRM+ signal and a FM signal (ΔF = 150 kHz and ΔP = 23 dBr)

Simulcast alternative 1: Delta-F = 150 kHz, delta-P = 23 dBr. Note, violation of ETSI FM spectrum mask.

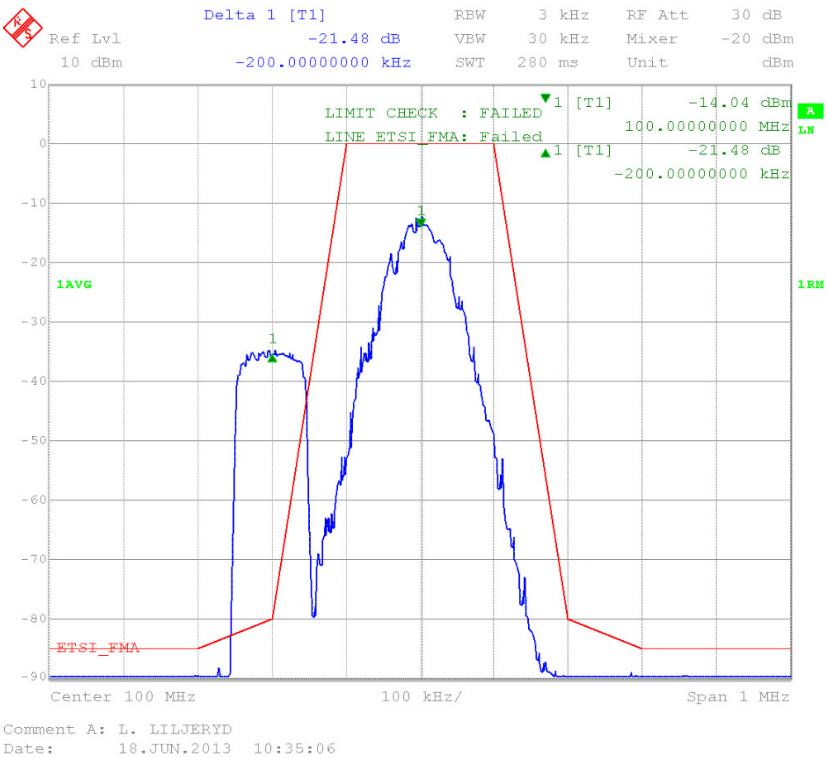

Fig. 6, **Simulcast alternative 2**

A Typical simulcast spectrum containing a DRM+ signal and a FM signal (ΔF = 200 kHz and ΔP = 20 dBr)

Simulcast alternative 2: Delta-F = 200 kHz, delta-P = 20 dBr. Note, violation of the ETSI FM spectrum mask in both examples and the broadcaster needs to apply for an adjacent channel license, if at all feasible and available.

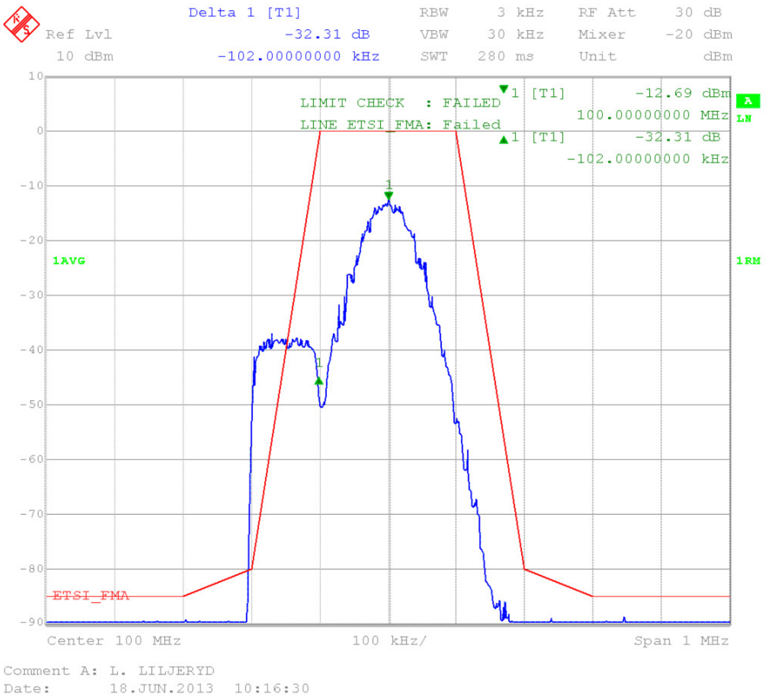

Fig. 7, **Simulcast alternative 1 clarification**

A Typical simulcast spectrum containing a DRM+ signal and a FM signal (ΔF = 150 kHz and ΔP = 23 dBr).

Note the typical flank-to center distance of 102 kHz.

Note that according to **Simulcast alternative 1** at delta-F of 150 kHz, the closest flank of the DRM+ spectrum is at a distance of 102 kHz from the FM carrier centre. This distance has to be at a given minimum to protect the FM receiver from DRM spectrum leakage due to wide RF filters in the FM receiver.

DRM30 and FM simulcast

DRM30 works excellent in the AM-band and has been successfully tested up to and including the 26 MHz shortwave band. However, the undersigned has found no reports of tests that evaluated DRM30 in the FM-band. The fact that the DRM30 radio-modem is not optimized for VHF frequencies is a limiting factor, thus excessive Doppler shift from moving receivers, may present a limiting factor on reception. This will be evaluated by us using a computerized channel simulator and practical tests.

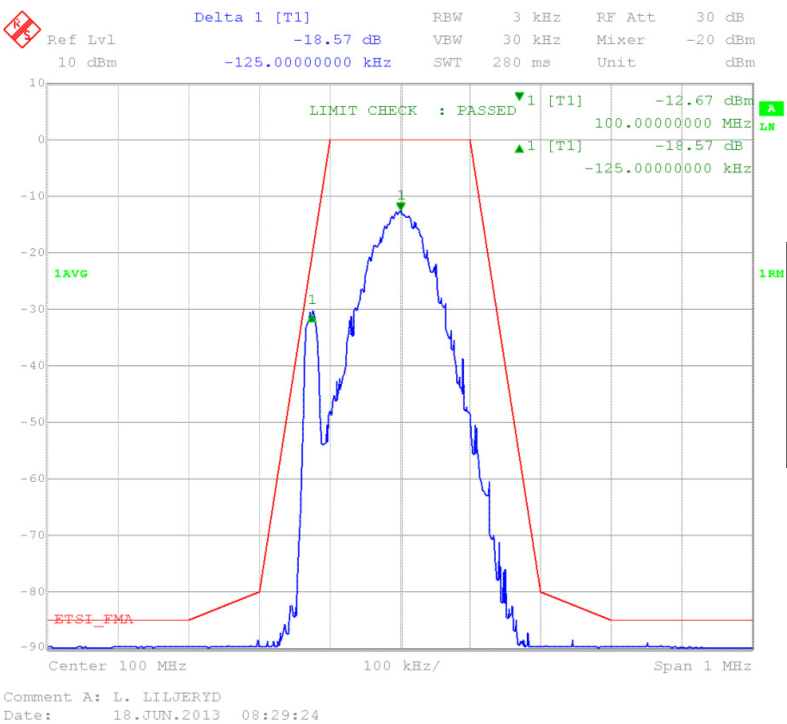

Fig. 8, **Simulcast alternative 3**

A new **Single Channel Simulcast** method (**SCS**) including a DRM30 signal and a FM signal (ΔF = 125 kHz and ΔP = 23 dBr).

Simulcast alternative 3: Note that it is possible to include the DRM30 20 kHz wide spectrum (Mode C) **within** the FM spectrum mask in the simulcast, thus creating Single Channel Simulcast (SCS) in the FM-band. Thus, the broadcaster is not violating the ETSI mask. The DRM+ signal delta-frequency is 125 kHz.

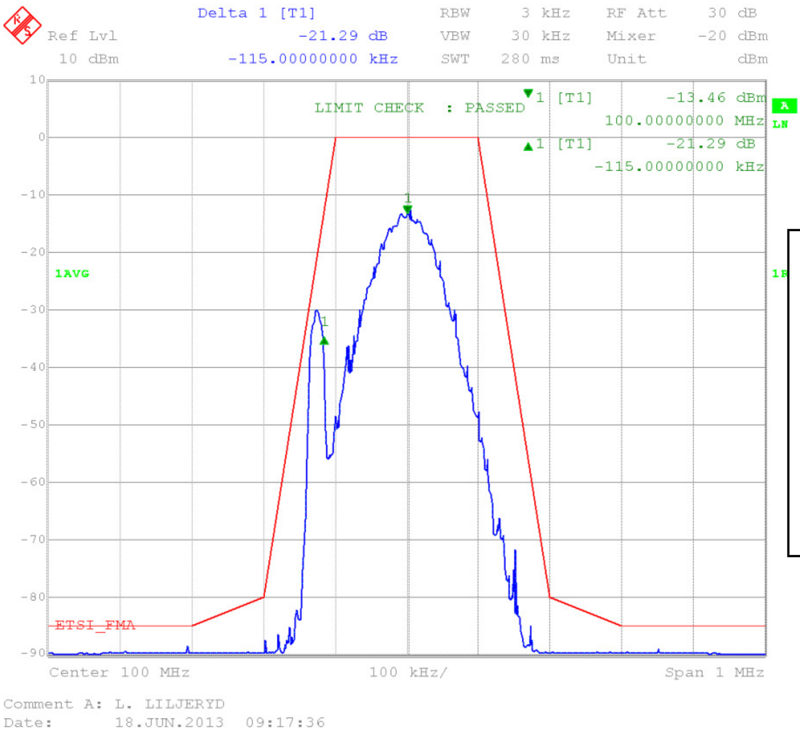

Fig. 9, **Simulcast alternative 3 clarification**

A new **Single Channel Simulcast** metod (**SCS**) including a DRM30 signal and a FM signal (ΔF = 125 kHz and ΔP = 23 dBr).

Note the improved flank-to-center distance of 115 kHz.

Simulcast alternative 3: Note, due to the smaller bandwidth of the DRM30 spectrum, the flank distance of the DRM30 spectrum is now improved from a distance of 102 kHz from the FM carrier centre, to 115 kHz. This improves the protection of the FM receiver to DRM interference. The DRM+ signal delta-frequency is 125 kHz.

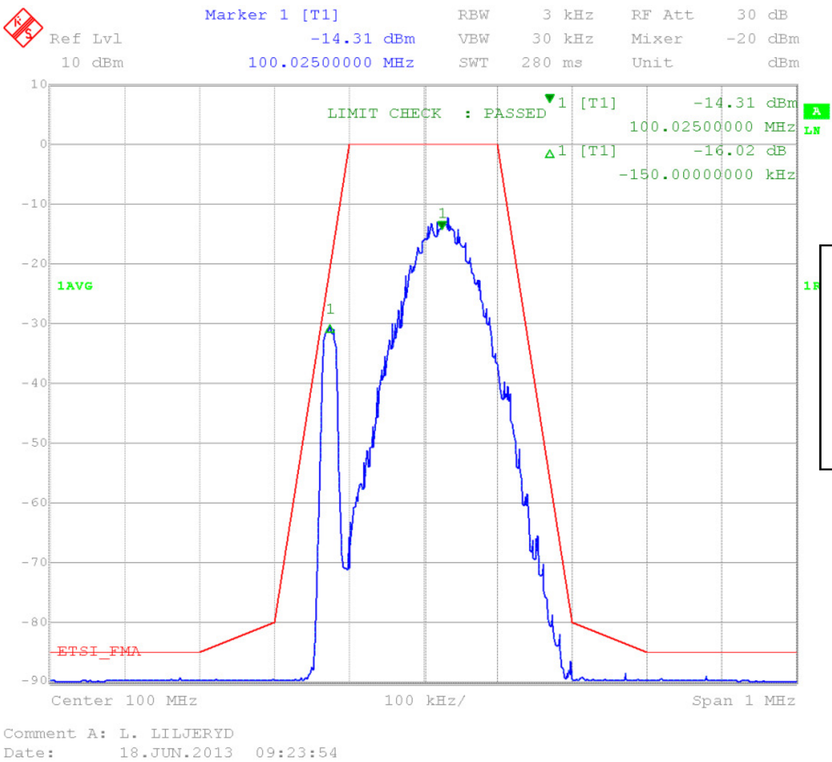

Fig. 10, **Simulcast alternative 4**

A new **Single Channel Simulcast** method (**SCS**) including a DRM30 signal and a FM signal (improved ΔF = 150 kHz and ΔP = 23 dBr).

Simulcast alternative 4: By utilizing the earlier mentioned “capture effect” inherent in FM demodulation, a slight offset of 25 kHz of the FM carrier to 100.025 MHz offers an even larger flank distance of the DRM30 spectrum from the FM carrier centre. The DRM30 signal delta-frequency is now 150 kHz, offering improved protection for low-quality, low-cost FM-receivers.

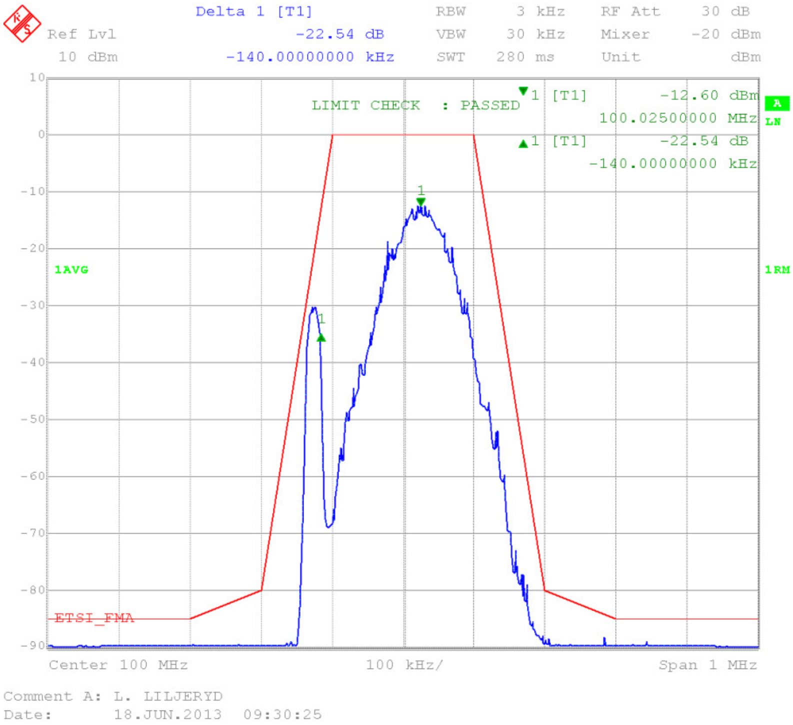

Fig. 11, **Simulcast alternative 4 clarification**

A new **Single Channel Simulcast** method (**SCS**) including a DRM30 signal and a FM signal (improved ΔF = 150 kHz and ΔP = 23 dBr).

Note the further improved flank-to center distance of 140 kHz.

Simulcast alternative 4: Note that the closest flank of the DRM30 spectrum is now substantially improved from the originally suggested DRM+ distance of 102 kHz of **Simulcast alternative 1** from the FM carrier centre, to 140 kHz, or not far from 152 kHz as of **Simulcast alternative 2**. This improvement is still achieved within the ETSI FM spectrum mask!

For comparative purposes, the American HD-Radio (Ibiquity) system has the closest OFDM flank at 129.4 kHz from the FM carrier centre. With the 25 kHz extra flank distance according to alternative 4, a clear audible improvement can be heard on a low-cost portable FM-receiver.

Thus, in a graceful transition phase from analogue to digital in the FM-band, it may be possible to use DRM30 mode-C in a **Single Channel Simulcast** configuration, offering both analogue FM and digital DRM30 broadcast within the same ETSI spectrum mask. This may be achieved without the need for additional spectrum or frequency planning. A maximum bitrate of 38 kbit/s in DRM30 mode-C will offer close to FM-like sound quality in stereo for the listener during the transition phase.

After the future analogue FM shut-down, the broadcaster only needs to reset the DRM-modulator from DRM30 to full 96 kHz DRM+ bandwidth to continue broadcasting with all the benefits that the full mode can offer. Thus a simple transition from DRM30 to DRM+ is achieved.

However, as mentioned earlier, the DRM30 radio modem is not optimized for VHF band II use and running DRM30 in VHF band II has never been tested before and no conclusion can be drawn at this stage of its feasibility without extensive practical testing and simulation.

Further testing and simulation will commence after relevant permits have been granted for test transmissions.