MIMO Channel Sounding Test Transmission: Signal Definition

1 Introduction

This document defines a channel sounding signal (based on DVB-T) intended to allow channel measurements to be carried out in two-transmitter co-polar or cross-polar configurations.

2 Technical summary

The proposed signal is based the OFDM format of DVB-T. This signal is defined in [1] and features a 1-in-12 pilot structure intended for channel estimation. The first transmitter radiates DVB-T scattered pilots, continual pilots and TPS pilots exactly as defined in [1]. Since 2-transmitter MIMO channel measurement is required, modifications to the signal for the second transmitter are necessary. These are as follows: on every other OFDM symbol, the sign of the scattered pilots is reversed (i.e. the pilot is inverted) with respect to that defined in [1]. In addition, continual pilots which lie on carriers which at times coincide with an inverted pilot are permanently inverted to allow consistency when they are indeed coincident.

TPS data is arbitrary as it is not anticipated it will be used in the channel measurement applications..

The data cells are assigned fixed BPSK data obtained from the DVB-T reference sequence of [1] para. 4.5.2.

3 Signal definition

3.1 OFDM frame structure

OFDM frame structure shall be as reference [1] paragraph 4.4 with the following changes/exceptions:

2k mode only
8MHz channel only

3.2 Reference signals

3.2.1 Location of scattered pilots

Reference information, taken from the reference sequence of [1] para. 4.5.2, is transmitted in scattered pilot cells in every symbol.

Scattered pilot cells are always transmitted at the "boosted" power level of 16/9 relative to data bearing carriers. Thus the corresponding modulation is given by:

$$\mathrm{Re}\{c_{m,l,k}\} = \frac{4}{3} \times 2\left(\frac{1}{2} - w_k\right)$$

$$\mathrm{Im}\{c_{m,l,k}\} = 0$$

where m is the frame index, k is the frequency index of the carriers and l is the time index of the symbols.

For the symbol of index l (l ranging from 0 to 67), carriers for which index k belongs to the subset

$k = K_{min} + 3 \times (l \bmod 4) + 12p$ (p integer, $p \geq 0$, k in range $[K_{min}; K_{max}]$) are scattered pilots.

The pilot insertion pattern is shown in figure 11 of [1] 4.5.3.

3.2.2 Location and modulation of continual pilots

In addition to the scattered pilots, 45 locations for continual[1] pilots are defined in [1] para. 4.5.4 for 2k mode.

All continual pilots are modulated according to the reference sequence, see ref.[1] para. 4.5.2.

The continual pilots are transmitted at "boosted" power level.

Thus the corresponding modulation is given by, on transmitter 1 of 2:

$$\mathrm{Re}\{c_{m,l,k}\} = \frac{4}{3} \times 2\left(\frac{1}{2} - w_k\right)$$

$$\mathrm{Im}\{c_{m,l,k}\} = 0$$

3.2.3 Modification to pilots on transmitter 2

Transmitter 2 has scattered pilots inverted every other OFDM symbol to allow for MIMO channel measurement. Continual pilots falling on scattered-pilot-bearing carriers are inverted compared to transmitter 1 if the coincident scattered pilot is inverted; continual pilots without this property are not inverted.

Scattered pilots on transmitter 2:

[1] i.e. occurring on all symbols

$$\mathrm{Re}\{c_{m,l,k}\} = \frac{4}{3} \times (-1)^l \times 2\left(\frac{1}{2} - w_k\right)$$ (symbol no. l in the range 0…67)

$$\mathrm{Im}\{c_{m,l,k}\} = 0$$

Continual pilots on transmitter 2:

$$\mathrm{Re}\{c_{m,l,k}\} = \frac{4}{3} \times (-1)^l \times 2\left(\frac{1}{2} - w_k\right) \text{ if } k \bmod 3 = 0$$

$$\mathrm{Re}\{c_{m,l,k}\} = \frac{4}{3} \times 2\left(\frac{1}{2} - w_k\right) \text{otherwise}$$

$$\mathrm{Im}\{c_{m,l,k}\} = 0$$

3.2.4 Amplitudes of all reference information

Reference [1] para 4.5.5 shall apply.

3.3 TPS pilots

This is defined in accordance with [1] para. 4.6, 2k mode, but may have arbitrary information in s_0-s_{67}.

3.4 Data carriers

3.4.1 Location and modulation of the data carriers

The set of data carriers associated with the l^{th} symbol of the m^{th} transmission frame has 1512 elements and is denoted here by $\{data\ carriers\}_{m,l}$. It is the complement of the set of reference and TPS carriers, and we shall index it with v in the range (0….1511)

Transmitter 1:

Data carriers $c^{(1)}_{m,l,v}$ depend only on the indices v and l and are given by

$$\mathrm{Re}\{c^{(1)}_{m,l,v}\} = 2\left(\frac{1}{2} - d_{v,l}\right) \text{for } v \in \{0 \ldots 1511\} \text{ and } l \in \{0...67\}$$

$$\mathrm{Im}\{c_{m,l,v}\} = 0$$

with $d_{v,l}$ as specified in the following section 3.4.2

Transmitter 2:

Data carriers $c_{m,l,v}^{(2)}$ depend on the indices v and l and are given by

$$\mathrm{Re}\left\{c_{m,l,v}^{(2)}\right\} = (-1)^l \times 2\left(\frac{1}{2} - d_{v,l}\right) \text{ for } v \in \{0 \ldots 1511\} \text{ and } l \in \{0 \ldots 67\}$$

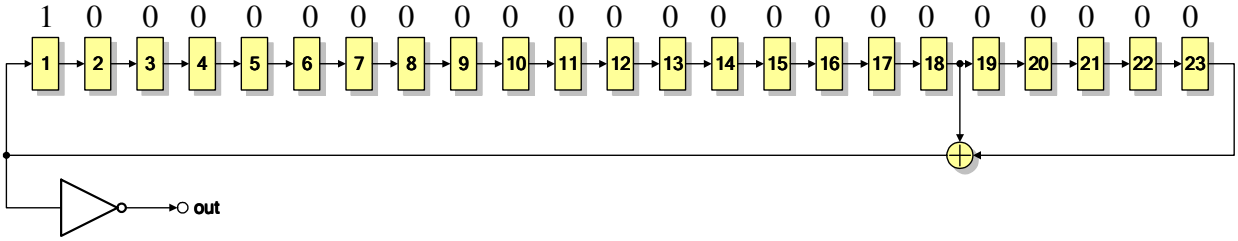
$$\mathrm{Im}\left\{c_{m,l,v}\right\} = 0$$

with $d_{v,l}$ as specified in the following section 3.4.2

3.4.2 PRBS sequence of the data carriers

The data carriers are modulated according to a different PRBS sequence, $d_{v,l}$, corresponding to their respective data carrier index v *and the frame index* l. This PRBS sequence with its initialisation sequence is shown in the diagram below.

Initialisation sequence



The PRBS is initialised so that the first output bit from the PRBS coincides with the first active carrier (data or signalling) of the first OFDM symbol in the frame, i.e. l=0. Subsequent bits from the sequence are mapped in order to the active carriers in the remaining symbols in the frame l=1 to l=67. However if the carrier is not a data carrier, the PRBS output is discarded. In this way, within the l^{th} symbol, 1705 bits are generated by the PRBS but only 1512 are used corresponding to v in the range 0…1511.

So if the sequence is u_m with $m \in 0 \ldots (1705 * 68) - 1$ then we can write (as pseudocode)

```
F=68;
P=1705;

for l=0:F-1
    v=0;
    for  p=0:P-1
        if carrier==data_carrier
            d(v,l)=u(p+l*P);
            v=v+1;
        end
    end
end
```

The The PRBS will be re-initialised at the start of every OFDM frame.

The polynomial for the PRBS generator for data carriers is

$$X^{23} + X^{18} + 1,$$

as specified by ITU-T recommendation O.151, clause 2.2.

4 References

[1] ETSI EN 300 744 V1.4.1 (2001-01) : Digital Video Broadcasting (DVB); Framing structure, channel coding and modulation for digital terrestrial television