D 2.4. PROTECTION OF THE RADIO ASTRONOMY SERVICE IN THE 150.05-153 MHZ BAND FROM HARMFUL INTERFERENCE FROM THE VDE-SAT DOWNLINK

An appropriate protection limit for Radio Astronomy service in the 150.05-153.0 MHz band would be −238 dBW/m^2 in a 2.95 MHz bandwidth centred around 152 MHz. Accordingly, the maximum VDE-SAT downlink emission in the 150.05-153 MHz band should be below values shown in Table 66.

Table 66 - Maximum satellite unwanted emissions in the 150.05-153 MHz band

Ship elevation angle (deg)	RAS limit (W/m^2/ 2.95 MHz)	Range (km)	Sat. max. interference e.i.r.p.		
			(W)	(dBW)	(dBW/Hz)
0	1.58E-24	2830	1.60E-10	−97.97	−162.67
10	1.58E-24	1932	7.43E-11	−101.29	−165.99
20	1.58E-24	1392	3.86E-11	−104.14	−168.83
30	1.58E-24	1075	2.30E-11	−106.38	−171.08
40	1.58E-24	882	1.55E-11	−108.10	−172.80
50	1.58E-24	761	1.15E-11	−109.38	−174.08
60	1.58E-24	683	9.29E-12	−110.32	−175.02
70	1.58E-24	635	8.03E-12	−110.95	−175.65
80	1.58E-24	608	7.36E-12	−111.33	−176.03
90	1.58E-24	600	7.17E-12	−111.44	−176.14

D 2.5. BIT MAPPING

For bit mappings, see Annex A.

D 2.6. SPREADING

Direct sequence spreading with constant envelope is applied for the physical layer burst format SAT-MCS-1.50-2, identified by Link Config ID 20. Spreading for the downlink burst waveforms carrying bulletin boards, Link Config ID 25 and Link Config ID 32 are achieved by utilising Gold sequences of length 2047. A short direct spreading sequence of length four is applied for the downlink burst waveforms defined by Link Config ID 28-31.

D 2.6.1. SPREAD SPECTRUM WITH CONSTANT ENVELOPE

Direct sequence spreading with constant envelope can be implemented according to the spreading strategy [RD-3]. This provides a way to generate constant envelope signals whilst allowing the use of linear modulations (i.e. BPSK, or QPSK for data modulation). In this approach, the CPM spreading sequences are selected such that the spread symbols maintain quasi continuous phase even at the transition from one symbol to the next. The CPM spreading principle is provided in Figure 52.

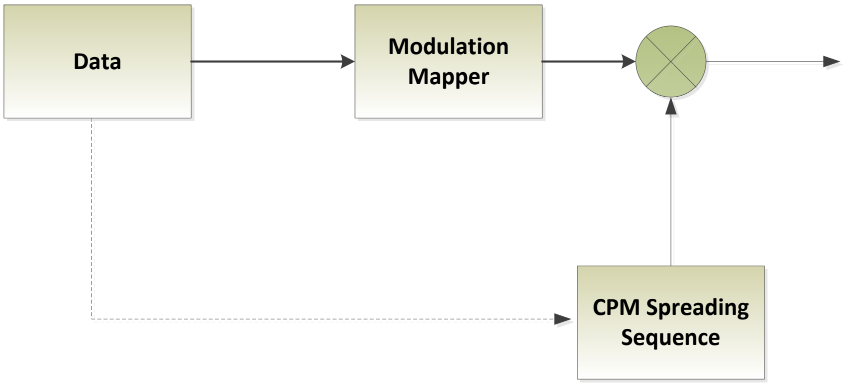

Figure 52 - CPM Spreading Principle

In order to avoid phase discontinuity at the data symbol transitions, the proposed solution is to adapt the spreading sequence to the modulation data. In other words, the CPM spreading sequence at the edge of each symbol is adapted according to the new input modulation symbol value to avoid any phase discontinuity. Such a solution produces a small loss at the receiver as the receiver does not know the edge symbol part of the used CPM spreading sequence. For a spreading factor of 16 or higher, the resulting correlation loss experienced by the receiver due to this issue is less than 0.25 dB. Performance losses with respect to conventional spreading is thus quite negligible provided that SF = 16 or larger is used.

The CPM spreading sequences are computed and optimized off-line and then stored in the memory of the terminals and receivers. A single spreading code is sufficient for all the users in the system. There is thus no need for storing multiple spreading sequences but just a single spreading sequence.

The stored spreading sequence (see G1139-1) is then applied starting from the preamble and continuing in the data part (as shown in Figure 41). The generated constant envelope spreading output sequence $y(k)$ is given by

$$y(k) = \begin{cases} x(n) \cdot cp_a\big(l_a, p_a(n)\big), & \text{for } m < SL/2 \\ x(n) \cdot cp_e\big(l_e, p_e(n)\big), & \text{otherwise} \end{cases}$$

where $x(n)$ represents the QPSK modulated input signal of length BL symbols. Thus, $n \in [0, BL-1]$. It should be noted that the generated spreading sequence $y(k)$ is actually partly dependent on the modulation symbols in order to ensure continuity of the signal phase when the modulation symbol changes (Figure 40). The spreading sequence to be generated is oversampled by a factor NS relative to the chip rate. The total number of constant envelope output samples then becomes $BS = BL \cdot SF \cdot NS$, where one single input QPSK symbol is spread to $SL = SF \cdot NS$ output samples. The output sample index k is ranging from 0 to $BS - 1$, and the input symbol index n as function of the output sample index k is related by $n = \lfloor k/SL \rfloor$. Here the floor operator $\lfloor u \rfloor$ rounds u down to the nearest integer towards minus infinity. Furthermore, two predefined two-dimensional complex valued tables, cp_a and cp_e, containing optimised constant envelope spreading signature sequences are utilised in the constant envelope spreading process. The table cp_a is applied for generating the spreading sequence for the first half of an input symbol, while cp_e is used for the second half, where a half symbol period consists of $SL/2$ output samples. The present table to use, either cp_a or cp_e, is decided by the modulus index value given by $m = k \,\%\, SL = k - SL \cdot \lfloor k/SL \rfloor = k - SL \cdot n$, where % defines a modulus operator. The first dimensional, representing sample time, table indexes l_a and l_e are given by $l_a = (m + n \cdot SL/2) \,\%\, TL = (k - n \cdot SL/2) \,\%\, TL$ and $l_e = (m + (n-1) \cdot SL/2) \,\%\, TL = (k - (n+1) \cdot SL/2) \,\%\, TL$, where TL is the first dimensional size of the cp_a and cp_e tables. In our case, the spreading sequence is designed as maximum length, i.e. $TL = BS/2$, $l_a \in [0,\ BS/2 - 1]$ and $l_e \in [0,\ BS/2 - 1]$. The modulus TL in the timing index expressions is not needed. The second dimensional table indexes, $p_a(n)$and $p_e(n)$, depend on $x(n)$ and are based on differential QPSK symbol quadrant computation. Given the applied Gray-coded QPSK bits-to-symbol mapping definition, the belonging quadrant is given by

$$q=\begin{cases}0, \text{ for QPSK input bits equal to } 11\\ 1, \text{ for QPSK input bits equal to } 01\\ 2, \text{ for QPSK input bits equal to } 00\\ 3, \text{ for QPSK input bits equal to } 10\end{cases}$$

and the second dimensional table indexes

$$p_a(n)=\begin{cases}0, & \text{for } n=0\\ \big(q(n)-q(n-1)\big)\ \%\ 4, & \text{for } n>0\end{cases}$$

and

$$p_e(n)=\begin{cases}\big(q(n+1)-q(n)\big)\ \%\ 4, & \text{for } n<BL-1\\ 0, & \text{for } n=BL-1\end{cases}$$

As the differential phase table indexes $p_a(n)$ and $p_e(n) \in [0,3]$, the overall size of the cp_a and the cp_e tables becomes $BS/2 \times 4$, thus containing $2 \cdot BS$ complex valued constant envelope values.

The specified constant envelope spreading scheme is at present only applicable for the SAT-MCS-1.50-2 physical layer burst format, with Link Config ID equal to 20, for which $BL = 261$ and $SF = 16$. The signature spreading sequences are optimised for an oversampling factor NS=16, and the cp_a signature table is stored in the ASCII file "cpa_SF16_NS16_BL261.txt", and the cp_e table is stored in file "cpe_SF16_NS16_BL261.txt". The table entities within the files are oriented in $BS/2$ rows and 8 columns. The row number thus directly related to the first dimensional table indexes, l_a and l_e. The first, third, fifth and seventh columns contain the real part of the complex valued entities, while the second, fourth, sixth and eighth columns hold the imaginary part. The full relationship between a loaded ASCII file table, $T[\quad]$, and a signature table $cp(\quad)$ becomes

$$cp(l,p) = T[l+1, 2p+1] + j \cdot T[l+1, 2p+2]$$

where $j = \sqrt{-1}$ and the row and column of $T[\quad]$ are assumed counted from one.

Even if the signature sequences are optimised for NS=16, appropriate constant envelope spreading sequences for NS=8 and NS=4 can be generated by decimating the signature spreading tables in time, i.e. along the first dimensional table index, by a decimation factor equal to 2 or 4 correspondingly.

Figure 54 illustrates the power spectral properties of the proposed modulation scheme (with spreading factor 16). Due to its constant envelope properties, this modulation scheme can operate with a transmit power amplifier operating close to saturation while maintaining a low power leakage to adjacent channels.

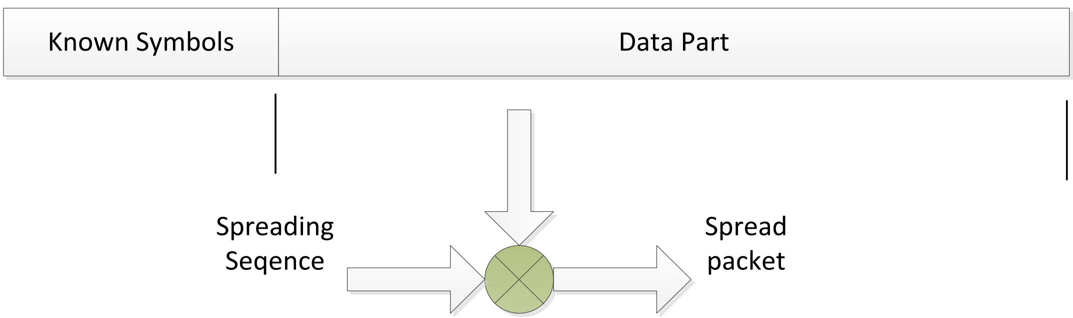

Figure 53 - Proposed Spreading in the CPM

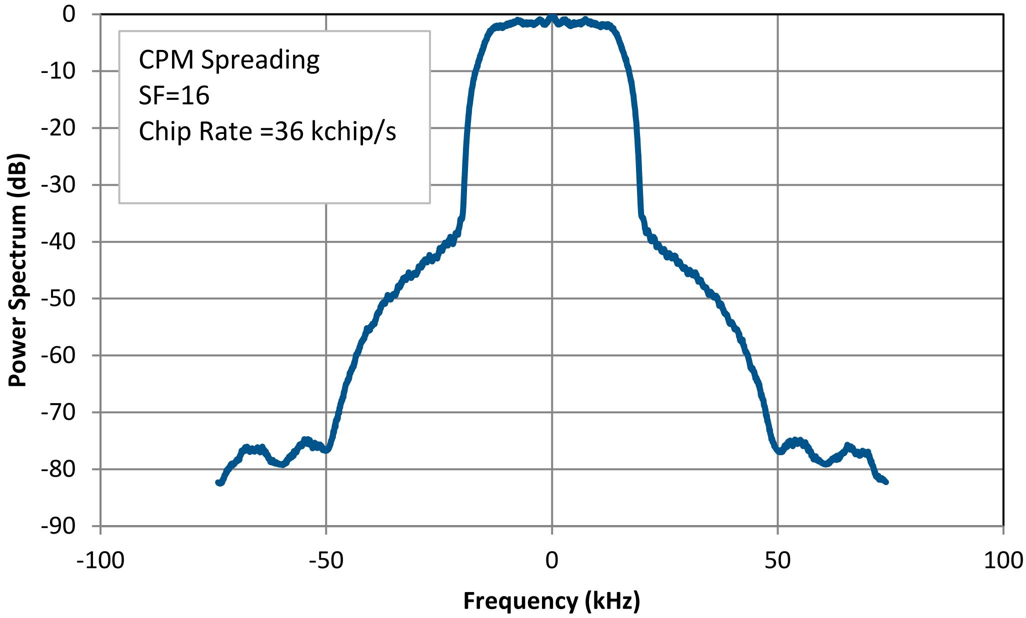

Figure 54 - Power spectral properties of spread spectrum with constant envelope

D 2.6.2. DIRECT SEQUENCE SPREADING FOR DOWNLINK WAVEFORMS

The waveform used for the bulletin board should allow for detection of overlapping signals received from two satellites. Two Gold spreading code sequences named SS0 and SS1 are selected to reduce the cross-correlation between delayed and frequency shifted versions of the overlapping waveforms. SS0 and SS1 is shown as byte oriented hexadecimal text strings in