

Prepared (also subject responsible if other)		No.		
EAB/RTL/I Palle Zetterstrand		B5KAKRC161028-4		
Approved	Checked	Date	Rev	Reference
EAB/RTL/I (P. Zetterstrand)		2004-12-08	A	

## Exhibit 12 – Cover Sheet

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**1 2.1033(c) Circuit Description**

**1.1 (2) FCC Identifier: B5KAKRC161028-4**

This RRU (Remote Radio Unit) consist of two synthesized transceivers (TRX) operating in the frequency band of 1930.4 to 1989.6 MHz. There are 297 Channels available with a channel spacing of 200 KHz. The transceiver is capable of operation in a TDMA (Time Division Multiple Access) system. For each channel there are 8 time slots available, each containing digital speech or data for GMSK and data for 8-PSK. The RRU have a hybrid combiner included which combines two TRX:s per antenna.

**1.2 (4) Type of Emission:**

**GMSK: 245KGXW**

**8-PSK: 245KG7W**

**1.3 (5) Frequency range: 1930.4 to 1989.6 MHz.**

**1.4 (6) Range of Operating Power:**

This transmitter is designed to supply a nominal power level of 41.5 dBm at the antenna connector. The power level can be set at 16 power levels, each with a 2 dB increment. The power levels are labeled P(0) to P(15) where P(0) is the highest power level.

**1.5 (7) Maximum Power Rating:**

The maximum power rating with one TRX under environmental and supply voltage variations is equal to 41.5 dBm plus a power level tolerance of +-2 dB. Therefore the maximum output power is 43.5 dBm equal to 22.4 W at the antenna connector of the radio base station.

**1.6 (8) Final Amplifier Voltage and Current in normal operation**

	P (0)	P (15)
Collector Voltage	29.5 Volt DC	29.5 Volt DC
Collector Current	2.2 Amps DC	0.4 Amps DC

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## 1.7 (10) Frequency Stabilizing Circuit Description

The transmitter in each TRX contains three synthesized oscillators. One PLL gives a 160 MHz signal to the I/Q modulator. The two other generate a 1770 to 1830 MHz signal to the mixer where the modulated signal is converted to the transmit frequency. Two oscillators are needed in frequency hopping mode, one is retuning while the other is active. All three synthesized oscillators have a reference of 13 MHz generated in a central synthesized oscillator (PLL) of 26 MHz, which is downmixed by 2, in the LTU part of the RRU. This PLL frequency reference is locked to a 3.25 MHz clock which is extracted from the multiplexed Y-interface MY. MY is generated and distributed by the IXU (Interface & Switching Unit) to all RRU:s in the base station.

The frequency reference 13 MHz in the IXU is generated in a voltage controlled oscillator phase-locked to the incoming PCM-link frequency or as an option an incoming GPS-link frequency.

## 1.8 (10) Spurious and Harmonic Suppression

Spurious and harmonic suppression is achieved by using two separate bandpass filters of ceramic type in the exciter. A filter module at the output works like a bandpass filter around the carrier. In addition to these filters, the output signal passes a cavity band pass filter in the combining system.

## 1.9 (10) Limiting Power

The TRX measures the output power at its output connector via a RF-detector and the detected value is used by the power loop control block to steer two variable gain attenuators between the modulator and the power amplifier.

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**1.10 (10) Digital Modulation**

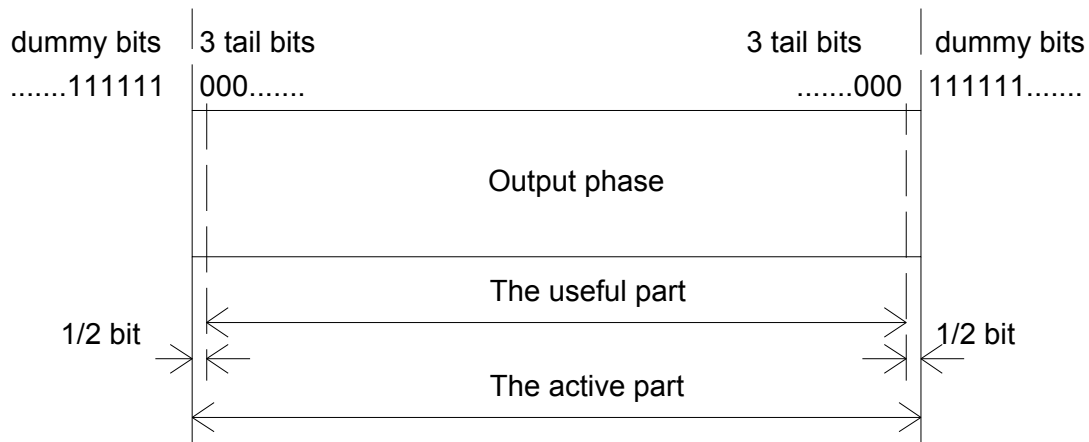
**1.10.1 Modulation format for GMSK**

1.10.1.1 Modulating symbol rate

The modulating symbol rate is  $1/T = 1\ 625/6$  ksymb/s (i.e. approximately 270.833 ksymb/s), which corresponds to  $1\ 625/6$  kbit/s (i.e. 270.833 kbit/s). T is the symbol period.

1.10.1.2 Start and stop of the burst

Before the first bit of the bursts as defined in GSM 05.02 [3] enters the modulator, the modulator has an internal state as if a modulating bit stream consisting of consecutive ones ( $d_j = 1$ ) had entered the differential encoder. Also after the last bit of the time slot, the modulator has an internal state as if a modulating bit stream consisting of consecutive ones ( $d_j = 1$ ) had continued to enter the differential encoder. These bits are called dummy bits and define the start and the stop of the active and the useful part of the burst as illustrated in figure 1. Nothing is specified about the actual phase of the modulator output signal outside the useful part of the burst.



**Figure 1: Relation between active part of burst, tail bits and dummy bits. For the normal burst the useful part lasts for 147 modulating bits**

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### 1.10.1.3 Differential encoding

Each data value  $d_j = [0, 1]$  is differentially encoded. The output of the differential encoder is:

$$\bar{d}_i = d_i \oplus d_{i-1} \quad (d_i \in \{0,1\})$$

where  $\oplus$  denotes modulo 2 addition.

The modulating data value  $\alpha_j$  input to the modulator is:

$$\alpha_i = 1 - 2\bar{d}_i \quad (\alpha_i \in \{-1, +1\})$$

### 1.10.1.4 Filtering

The modulating data values  $\alpha_j$  as represented by Dirac pulses excite a linear filter with impulse response defined by:

$$g(t) = h(t) * \text{rect}\left(\frac{t}{T}\right)$$

where the function  $\text{rect}(x)$  is defined by:

$$\text{rect}\left(\frac{t}{T}\right) = \frac{1}{T} \quad \text{for } |t| < \frac{T}{2}$$

$$\text{rect}\left(\frac{t}{T}\right) = 0 \quad \text{otherwise}$$

and \* means convolution.  $h(t)$  is defined by:

$$h(t) = \frac{\exp\left(\frac{-t^2}{2\delta^2 T^2}\right)}{\sqrt{(2\pi) \cdot \delta T}}$$

where  $\delta = \frac{\sqrt{\ln(2)}}{2\pi BT}$  and  $BT = 0.3$

where B is the 3 dB bandwidth of the filter with impulse response  $h(t)$ . This theoretical filter is associated with tolerances defined in GSM 05.05 [4].

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1.10.1.5 Output phase

1.10.1.6 The phase of the modulated signal is:

$$\varphi(t') = \sum_i \alpha_i \pi h \int_{-\infty}^{t'-iT} g(u) du$$

where the modulating index  $h$  is 1/2 (maximum phase change in radians is  $\pi/2$  per data interval).

The time reference  $t' = 0$  is the start of the active part of the burst as shown in figure 1. This is also the start of the bit period of bit number 0 (the first tail bit) as defined in GSM 05.02 [2].

1.10.1.7 Modulation

The modulated RF carrier, except for start and stop of the TDMA burst may therefore be expressed as:

$$x(t') = \sqrt{\frac{2E_c}{T}} \cdot \cos(2\pi f_0 t' + \varphi(t') + \varphi_0)$$

where  $E_c$  is the energy per modulating bit,  $f_0$  is the centre frequency and  $\varphi_0$  is a random phase and is constant during one burst.

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**1.10.2 Modulation format for 8PSK**

1.10.2.1 Modulating symbol rate

The modulating symbol rate is  $1/T = 1\ 625/6$  ksymb/s (i.e. approximately 270.833 ksymb/s), which corresponds to  $3 \cdot 1\ 625/6$  kbit/s (i.e. 812.5 kbit/s). T is the symbol period.

1.10.2.2 Symbol mapping

The modulating bits are Gray mapped in groups of three to 8PSK symbols by the rule

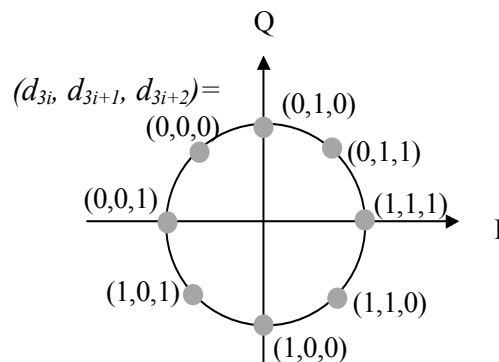
$$s_i = e^{j2\pi l/8}$$

where  $l$  is given by table 1.

**Table 1: Mapping between modulating bits and the 8PSK symbol parameter  $l$ .**

Modulating bits $d_{3i}, d_{3i+1}, d_{3i+2}$	Symbol parameter $l$
(1,1,1)	0
(0,1,1)	1
(0,1,0)	2
(0,0,0)	3
(0,0,1)	4
(1,0,1)	5
(1,0,0)	6
(1,1,0)	7

This is illustrated in figure 2.

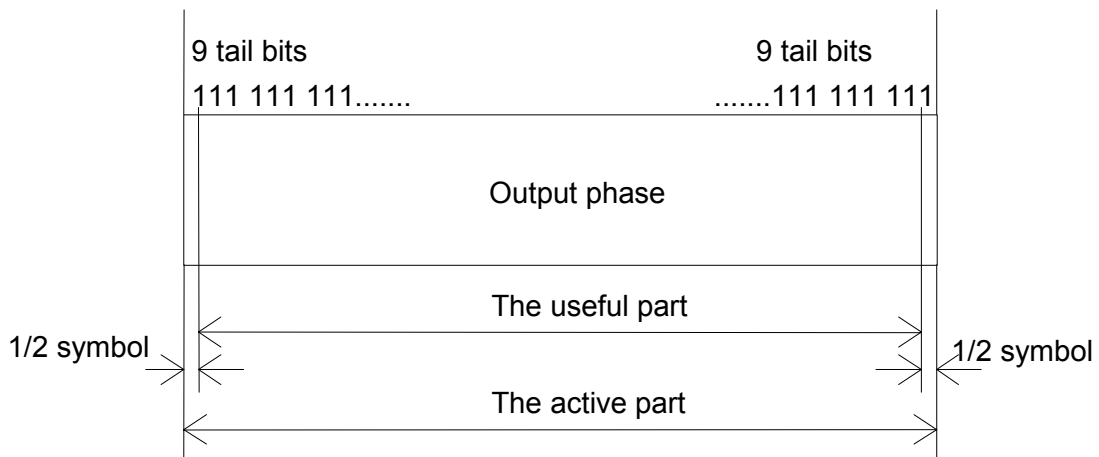


**Figure 2: Symbol mapping of modulating bits into 8PSK symbols.**

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1.10.2.3 Start and stop of the burst

Before the first bit of the bursts as defined in GSM 05.02 [3] enters the modulator, the state of the modulator is undefined. Also after the last bit of the burst, the state of the modulator is undefined. The tail bits (see GSM 05.02) define the start and the stop of the active and the useful part of the burst as illustrated in figure 3. Nothing is specified about the actual phase of the modulator output signal outside the useful part of the burst.



**Figure 3: Relation between active part of burst and tail bits. For the normal burst the useful part lasts for 147 modulating symbols**

1.10.2.4 Symbol rotation

The 8PSK symbols are continuously rotated with  $3\pi/8$  radians per symbol before pulse shaping. The rotated symbols are defined as

$$\hat{s}_i = s_i \cdot e^{ji3\pi/8}$$

1.10.2.5 Pulse shaping

The modulating 8PSK symbols  $\hat{s}_i$  as represented by Dirac pulses excite a linear pulse shaping filter. This filter is a linearised GMSK pulse, i.e. the main component in a Laurant decomposition of the GMSK modulation. The impulse response is defined by:

$$c_0(t) = \begin{cases} \prod_{i=0}^3 S(t+iT), & \text{for } 0 \leq t \leq 5T \\ 0, & \text{else} \end{cases}$$

where



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$$S(t) = \begin{cases} \sin(\pi \int_0^t g(t') dt'), & \text{for } 0 \leq t \leq 4T \\ \sin(\frac{\pi}{2} - \pi \int_0^{t-4T} g(t') dt'), & \text{for } 4T < t \leq 8T \\ 0, & \text{else} \end{cases}$$

$$g(t) = \frac{1}{2T} \left( Q(2\pi \cdot 0.3 \frac{t-5T/2}{T\sqrt{\log_e(2)}}) - Q(2\pi \cdot 0.3 \frac{t-3T/2}{T\sqrt{\log_e(2)}}) \right)$$

and

$$Q(t) = \frac{1}{\sqrt{2\pi}} \int_t^{\infty} e^{-\frac{\tau^2}{2}} d\tau.$$

The base band signal is

$$y(t') = \sum_i \hat{s}_i \cdot c_0(t' - iT + 2T)$$

The time reference  $t' = 0$  is the start of the active part of the burst as shown in figure 3. This is also the start of the symbol period of symbol number 0 (containing the first tail bit) as defined in GSM 05.02 [2].

#### 1.10.2.6 Modulation

The modulated RF carrier during the useful part of the burst is therefore:

$$x(t') = \sqrt{\frac{2E_s}{T}} \operatorname{Re} \left[ y(t') \cdot e^{j(2\pi f_0 t' + \varphi_0)} \right]$$

where  $E_s$  is the energy per modulating symbol,  $f_0$  is the centre frequency and  $\varphi_0$  is a random phase and is constant during one burst.