Physical Layer Design for a Narrow Band Communication System

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Abstract—**The design and implementation of a simple narrow band communication system is provided in this document. TCM-8PSK is used for modulation, followed by channel estimation and equalization in the presence of Rayleigh fading. Through simulation results, it is shown that the proposed system is robust.**

Download all python codes from

```
svn co https://github.com/SiddharthPh/
    Summer2020/trunk/geometry/codes
```

and latex-tikz codes from

```
svn co https://github.com/gadepall/school/trunk/
    ncert/geometry/figs
```

1 Specifications

The specifications for the communication system to be designed are listed in Table 1.

2 8-PSK

2.1 Modulation

2.1.1. See Fig. **??** for the constellation diagram. The transmitted symbol set is given by

$$\mathbf{s}_m = \begin{pmatrix} \cos\frac{2m\pi}{8} \\ \sin\frac{2m\pi}{8} \end{pmatrix}, \quad m \in \{0, 1, \dots, 7\}. \tag{2.1.1.1}$$

The numerical values for $\mathbf{s}_m$ are listed in Table **??**

2.1.2. The gray code shown in Table **??** is used for encoding the 8-PSK symbols.

2.1.3. The received symbol is then obtained as

$$\mathbf{y} = \sqrt{E_s}\mathbf{s} + \mathbf{n} \tag{2.1.3.1}$$

where E_s is the symbol energy and

$$\mathbf{n} \sim \mathcal{N}\left(\mathbf{0}, \frac{N_0}{2}\mathbf{I}\right) \tag{2.1.3.2}$$

$$\mathbf{s} \in \{\mathbf{s}_m\}_{m=0}^{7} \tag{2.1.3.3}$$

Parameter	**Value**
Hardware	FPGA based baseband
MODEM	8PSK-TCM
Modem Rate	555Kbps
SNR	7.6 db at 1e5
Channel (V/UHF)	30Mhz - 512Mhz
Bandwidth	250khz
Bit Duration	2.7us
Throughput	100kbps (Throughput at application Layer)
Ramp up time	116 us (Junk symbols will be sent)
Propagation Delay	100 us (Junk symbols will be sent)
Training sequence	421.2us(provided time for training sequence)
Frame Slot	2 ms
Frame SOM	8 bytes
Payload	32 bytes (692 us)

TABLE 1: Specifications

2.1.4. The decision rule is given by Fig. **??** and can be expressed as
Let $\mathbf{r}$ be the received bits, $\mathbf{r} = [r_1,r_2,r_3]$.

$$r_1 = \begin{cases} 0, & \mathbf{y} \in D1 \cup D2 \cup D3 \cup D4 \Leftrightarrow y_1(\sqrt{2}-1) + y_2 > \\ 1, & \mathbf{y} \in D5 \cup D6 \cup D7 \cup D8 \Leftrightarrow y_1(\sqrt{2}-1) + y_2 < \end{cases} \tag{2.1.4.1}$$

$$r_2 = \begin{cases} 0, & \mathbf{y} \in D2 \cup D1 \cup D8 \cup D7 \iff y_2 - (\sqrt{2}+1)y_1 \\ 1, & \mathbf{y} \in D3 \cup D4 \cup D5 \cup D6 \iff y_2 - (\sqrt{2}+1)y_1 \end{cases} \tag{2.1.4.2}$$

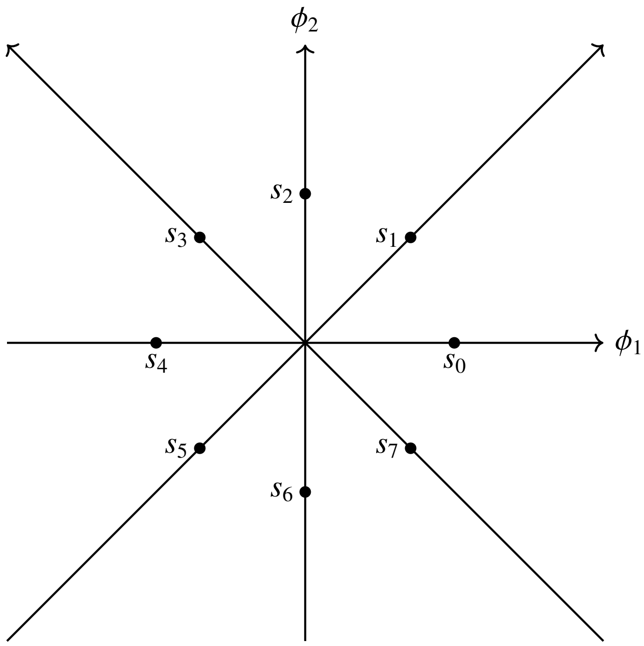

Fig. 2.1.1.1: Constellation diagram

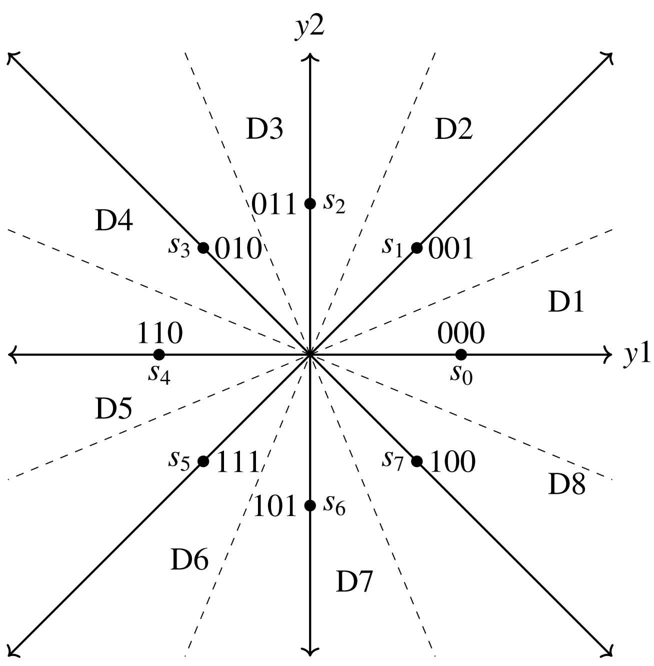

Fig. 2.1.4.1: decision regions

$$r_3 = \begin{cases} 0, & \mathbf{y} \in D4 \cup D5 \cup D1 \cup D8 \iff y_2 + (\sqrt{2}+1)y_1 < 0, y_2 - (\sqrt{2}-1)y_1 > 0 \\ 1, & \mathbf{y} \in D2 \cup D3 \cup D6 \cup D7 \iff y_2 + (\sqrt{2}+1)y_1 > 0, y_2 - (\sqrt{2}-1)y_1 < 0 \end{cases} \tag{2.1.4.3}$$

From eq.2.1.4.1,eq.2.1.4.2 and eq.2.1.4.3
For detecting s_0, $y_2 + (\sqrt{2}-1)y_1 > 0$ and $y_2 - (\sqrt{2}-1)y_1 < 0$.
For detecting s_1, $y_2 - (\sqrt{2}+1)y_1 < 0$ and $y_2 - (\sqrt{2}-1)y_1 > 0$.
For detecting s_2, $y_2 - (\sqrt{2}+1)y_1 > 0$ and $y_2 + (\sqrt{2}+1)y_1 > 0$.
For detecting s_3, $y_2 + (\sqrt{2}-1)y_1 > 0$ and $y_2 + (\sqrt{2}+1)y_1 < 0$.
For detecting s_4, $y_2 + (\sqrt{2}-1)y_1 < 0$ and $y_2 - (\sqrt{2}-1)y_1 > 0$.
For detecting s_5, $y_2 - (\sqrt{2}+1)y_1 > 0$ and $y_2 - (\sqrt{2}-1)y_1 < 0$.
For detecting s_6, $y_2 - (\sqrt{2}+1)y_1 < 0$ and $y_2 + (\sqrt{2}+1)y_1 < 0$.
For detecting s_7, $y_2 + (\sqrt{2}-1)y_1 < 0$ and $y_2 + (\sqrt{2}+1)y_1 > 0$.

2.1.5. The following code has simulation of 8PSK.

```
codes/8psk.py
```