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ACDA5008 - Digital Signal
Processing and Communication

Assignment - Simulation of Digital
Modulation Techniques

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Introduction

Information can be passed between different systems using a variety of methods if using physical electrical connections; protocols such as I2C and SPI have been developed to enable efficient communication. For wireless communication it's not possible to use these protocols alone due to their digital nature and we must instead modulate the digital signal with an analogue sinusoidal signal that can be transmitted over radio waves.

Digital data can be modulated in different ways depending on the system requirements and the transmission reliability that is needed. This report will look at the performance of Amplitude Shift Keying (ASK) and Phase Shift Keying (PSK) systems and how the reliability of both systems degrades with the introduction of Additive White Gaussian Noise (AWGN) into the transmission medium.

Amplitude Shift Keying (ASK) is a process by which a carrier wave is transmitted or suppressed based on the binary signal being fed into the modulator. Upon receiving a binary 1 the modulator transmits the carrier wave, and upon receiving a binary zero the modulator suppresses the carrier wave, this is known as On-Off keying. ASK modulation can also be achieved by the transmission of a carrier wave at two different amplitudes, known as Binary ASK [1]. It is also possible to design a modulator with multiple carrier amplitudes, allowing for more symbols to be transmitted at the same time and thus increasing the efficiency of the system. ASK modulation is only used today for low data rate systems and is widely used by the amateur radio community in the form of morse code.

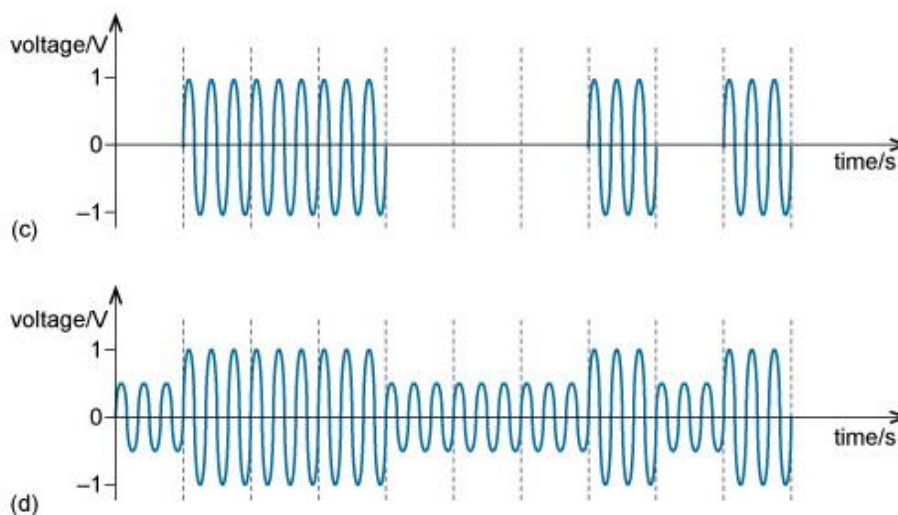


Figure 1 - example of On-Off Keying (top) and Binary ASK (bottom) for the same data source
credit The Open University

Phase Shift Keying (PSK) transmits a constant amplitude, but switches between two carrier waves out of phase with each other by 180° . This modulation technique is also known as Phase Reversal Keying (PRK) [2]. PSK was employed in the 1980's within public landline telephone networks and is widely used today within the Wi-Fi and Bluetooth communication protocols.

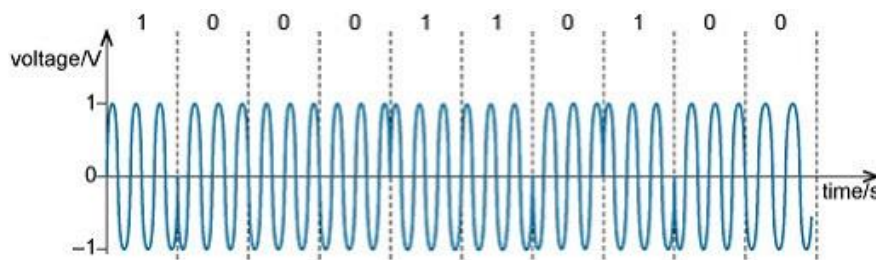


Figure 2 - example of Phase Shift Keying
credit The Open University

Simulation Models

To enable the investigation into modulation performance, two systems were developed within Mathworks Simulink. The ASK system was designed with a random binary input as a data source into the modulator and the demodulator outputting to an oscilloscope and an Error Rate Calculator. The Additive White Gaussian Noise module can be seen inline with the system transmission line, simulating a transmission line of increasing noise levels to test the reliability of the system.

Amplitude Shift Keying (ASK) Modulation

The carrier wave amplitude is changed between discrete levels (usually two) in accordance with the digital data.

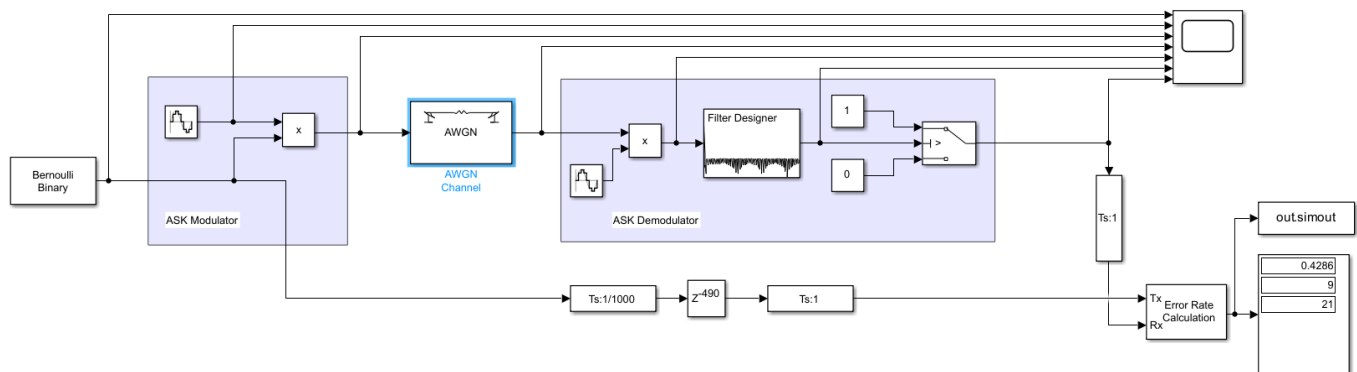
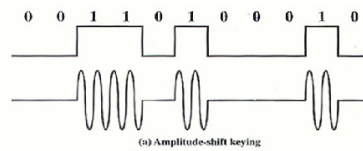


Figure 3 - Block diagram of the ASK Modulator and Demodulator designed within Mathworks Simulink

A similar test setup can be seen below for the PSK system, with a random binary data source fed into the modulator then the demodulator outputting to an oscilloscope and an Error Rate Calculator.

Phase-Shift Keying Modulation

Uses two phases to represent binary digits

$$s(t) = \begin{cases} A \cos(2\pi f_c t) & \text{binary 1} \\ A \cos(2\pi f_c t + \pi) & \text{binary 0} \end{cases}$$

$$= \begin{cases} A \cos(2\pi f_c t) & \text{binary 1} \\ -A \cos(2\pi f_c t) & \text{binary 0} \end{cases}$$

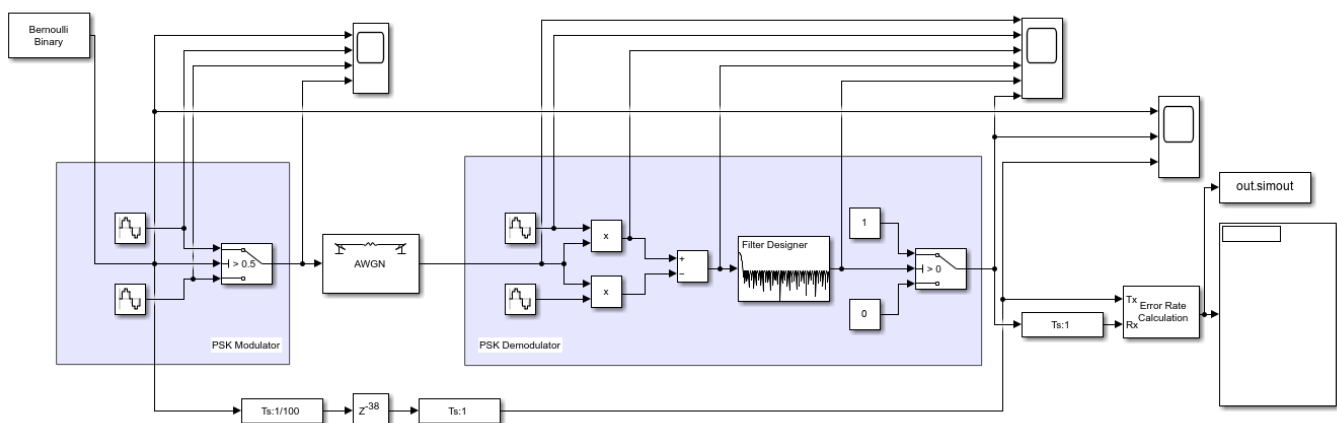


Figure 4 - Block diagram of the PSK Modulator and Demodulator designed within Mathworks Simulink

ASK Modulator

The block diagram for the Amplitude Shift Keying Modulator is very simple, comprising a carrier wave of 2Hz with an amplitude of 1 fed into a product multiplier which provides the output. When the binary input generates a 1, the product multiplier outputs the carrier wave, and when a binary 0 is generated the product multiplier outputs nothing.

The demodulator (seen in

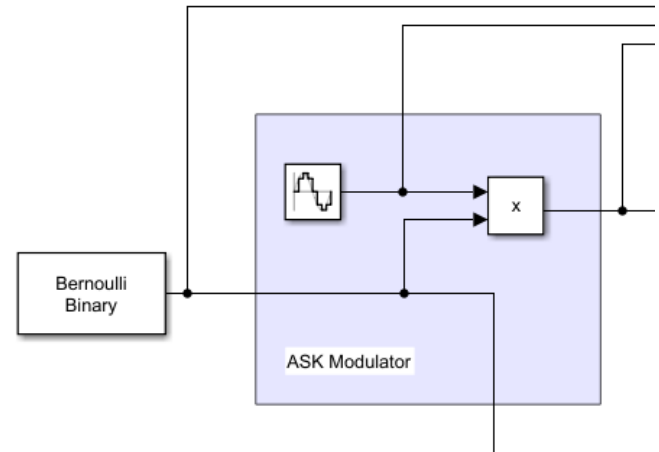


Figure 5 - The ASK Modulator in more detail

Figure 6) passes the received signal, and a local oscillator signal of the same frequency and amplitude as that of the modulator, through a product multiplier and then a filter to produce a clean signal, void of any high frequency noise.

The signal is then passed into a switch with a amplitude threshold of 0.5 to translate the signal into a clean binary data stream. The filter is designed with an Fpass of 1.25Hz and an Fstop of 4Hz and 80dB of rejection with an order of 920.

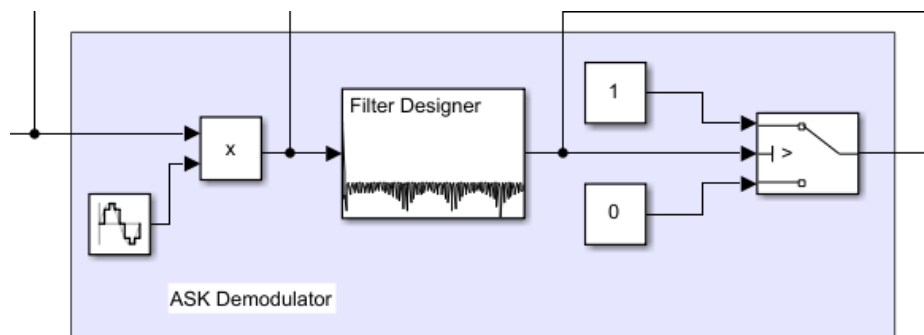


Figure 6 - The ASK Demodulator in more detail

The process of modulating and more importantly demodulating does take some time, therefore when viewed on an oscilloscope a time delay of 490ms is seen between the inputted binary data stream and the output. Therefore for the purposes of testing the system additional delays are added in line with the test wires breaking out the signal to the Error Rate Calculator module.

PSK Modulator

The block diagram for the PSK modulator can be seen in Figure 7 with two local oscillators π radians out of phase from each other at 2Hz inputting into a switch with a threshold of 0.5. The switch has the binary data source as its input, and outputs the carrier wave of one phase or the other dependant on the binary 1 or 0.

The demodulator can be seen in Figure 8 and features two of the same local oscillators which are of the same frequency and phase coherent with the oscillators in the modulator. The received signal is passed into two product multipliers and then a subtraction block before being passed through a filter and a binary switch in the same method as with the ASK demodulator. To reduce the delay imparted on the signal by the demodulator, and specifically the filter, a lower order filter was designed with an Fpass of 1 and an Fstop of 2.5 and only 30dB of rejection, resulting in a order of 76 and a time delay of only 38ms.

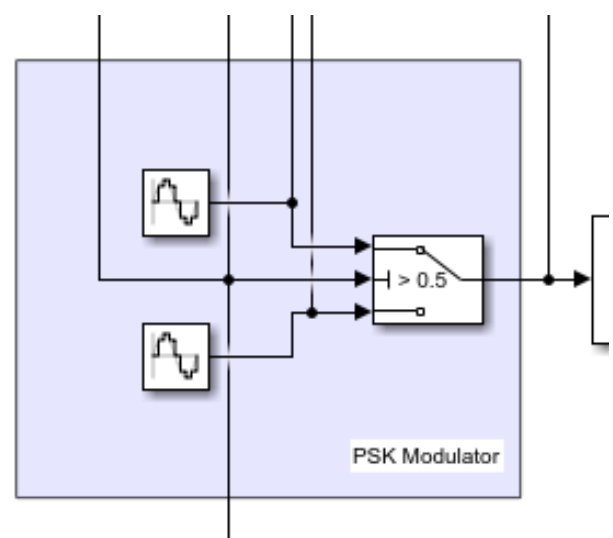


Figure 7 - PSK Modulator in more detail

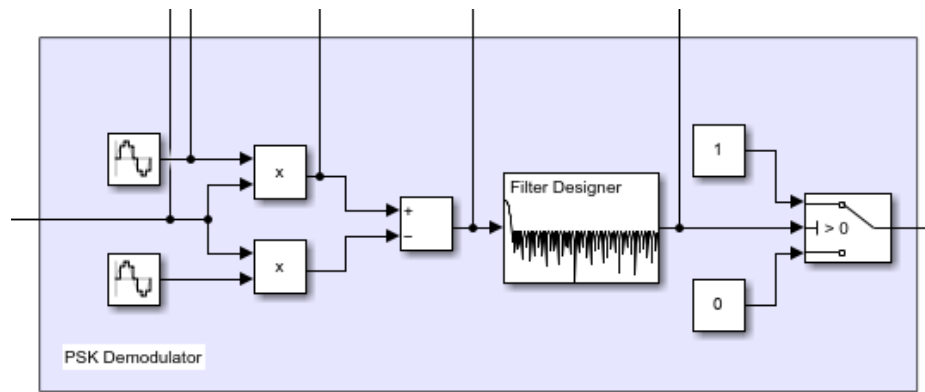


Figure 8 - The PSK demodulator in more detail

Results

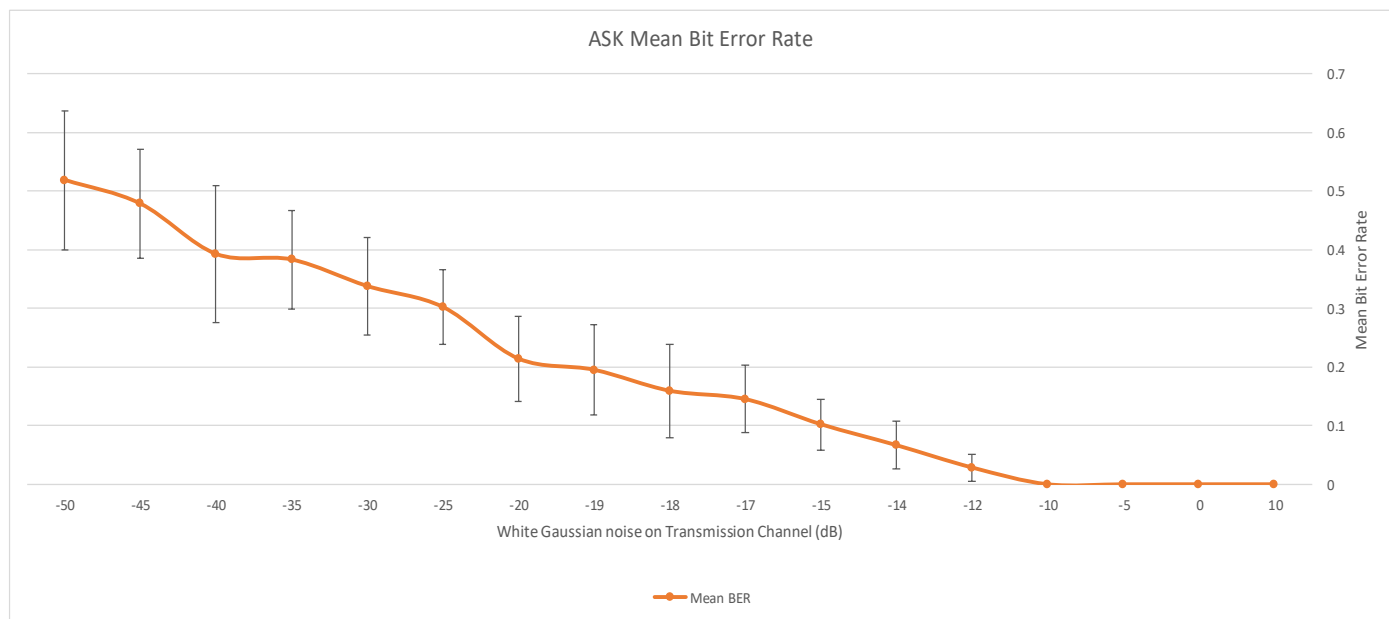


Figure 9 - Graph showing the error rate of the ASK demodulation as the noise on the transmission line increases

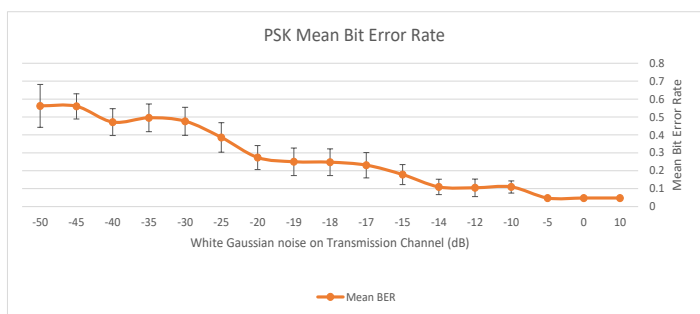


Figure 10 - Graph showing the error rate of the PSK demodulation increasing as the noise on the transmission line increases

Discussion

As seen in the above results, both systems suffer a reduction in reliability as the signal to noise ratio is decreased on the transmission line.

Conclusion

As seen in the above results, both systems suffer a reduction in reliability as the signal to noise ratio is decreased on the transmission line.

References

- [1] F.R.Connor, Introductory Topics in Electronics and Telecommunication (Modulation), Second Edition ed., London: Edward Arnold (Publishers) Ltd, 1982, p. Page 68.
- [2] F.R.Connor, Introductory Topics in Electronics and Telecommunication (Modulation), Second Edition ed., London: Edward Arnold (Publishers) Ltd, 1982, p. Page 70.

Appendix A: ASK

See spreadsheet. Insert Word Native table of results

Noise (dB)	Runs																				Mean BER
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
-5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0
-12	0.05	0.05	0.05	0.05	0.05	0.00	0.00	0.05	0.00	0.00	0.00	0.05	0.05	0.00	0.05	0.05	0.00	0.05	0.00	0.05	0.028572
-14	0.10	0.10	0.10	0.05	0.10	0.14	0.10	0.05	0.05	0.05	0.00	0.05	0.10	0.00	0.05	0.00	0.05	0.05	0.10	0.14	0.066672
-15	0.10	0.05	0.14	0.14	0.14	0.19	0.14	0.05	0.14	0.05	0.05	0.10	0.10	0.05	0.14	0.10	0.05	0.10	0.14	0.10	0.10238095
-17	0.10	0.14	0.19	0.10	0.10	0.10	0.14	0.14	0.14	0.19	0.10	0.05	0.10	0.14	0.10	0.29	0.19	0.24	0.19	0.19	0.1452381
-18	0.10	0.10	0.14	0.05	0.33	0.14	0.10	0.24	0.14	0.24	0.14	0.14	0.24	0.10	0.10	0.33	0.10	0.10	0.14	0.24	0.15952381
-19	0.19	0.19	0.24	0.24	0.24	0.14	0.24	0.24	0.19	0.05	0.00	0.19	0.38	0.19	0.14	0.24	0.24	0.24	0.19	0.14	0.1952381
-20	0.14	0.10	0.24	0.14	0.33	0.14	0.14	0.19	0.24	0.29	0.24	0.29	0.24	0.10	0.33	0.19	0.29	0.24	0.29	0.14	0.21428571
-25	0.29	0.38	0.33	0.29	0.19	0.24	0.38	0.29	0.33	0.29	0.14	0.29	0.33	0.38	0.29	0.29	0.38	0.24	0.38	0.33	0.30238095
-30	0.33	0.43	0.48	0.38	0.38	0.38	0.38	0.29	0.24	0.48	0.38	0.29	0.24	0.29	0.19	0.43	0.19	0.38	0.33	0.29	0.33809524
-35	0.48	0.33	0.43	0.38	0.48	0.29	0.48	0.33	0.52	0.48	0.43	0.38	0.38	0.19	0.33	0.29	0.38	0.33	0.29	0.48	0.38333333
-40	0.48	0.14	0.43	0.43	0.24	0.57	0.43	0.52	0.24	0.38	0.57	0.48	0.33	0.52	0.24	0.29	0.38	0.48	0.33	0.38	0.39285714
-45	0.62	0.43	0.48	0.48	0.48	0.62	0.48	0.67	0.33	0.52	0.33	0.33	0.43	0.43	0.43	0.48	0.62	0.52	0.48	0.43	0.47857143
-50	0.62	0.43	0.67	0.38	0.48	0.48	0.62	0.67	0.57	0.71	0.57	0.24	0.57	0.43	0.62	0.57	0.48	0.48	0.48	0.33	0.51904762

Appendix B: PSK

Runs																					Mean BER
Noise (dB)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
20	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	
10	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.04761905
0	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.04761905
-5	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.04761905
-10	0.10	0.14	0.14	0.10	0.14	0.14	0.10	0.14	0.10	0.10	0.14	0.14	0.10	0.05	0.05	0.10	0.14	0.10	0.05	0.14	0.10952381
-12	0.14	0.14	0.05	0.19	0.05	0.19	0.05	0.10	0.10	0.14	0.14	0.05	0.05	0.10	0.10	0.14	0.14	0.14	0.05	0.05	0.1047619
-14	0.14	0.10	0.14	0.14	0.14	0.10	0.05	0.05	0.10	0.14	0.10	0.19	0.05	0.19	0.05	0.14	0.10	0.10	0.10	0.10	0.10952381
-15	0.14	0.24	0.14	0.24	0.24	0.24	0.24	0.14	0.19	0.10	0.10	0.19	0.24	0.14	0.10	0.14	0.14	0.19	0.14	0.29	0.17857143
-17	0.33	0.10	0.29	0.10	0.29	0.19	0.24	0.19	0.33	0.29	0.29	0.19	0.19	0.24	0.19	0.14	0.24	0.33	0.29	0.19	0.23095238
-18	0.29	0.14	0.38	0.33	0.24	0.33	0.19	0.33	0.29	0.19	0.14	0.14	0.33	0.14	0.19	0.19	0.29	0.29	0.29	0.24	0.24761905
-19	0.19	0.33	0.19	0.29	0.24	0.14	0.24	0.29	0.38	0.10	0.24	0.29	0.33	0.14	0.33	0.24	0.33	0.29	0.14	0.29	0.25
-20	0.19	0.29	0.29	0.43	0.29	0.24	0.24	0.33	0.24	0.33	0.19	0.19	0.33	0.24	0.29	0.33	0.38	0.19	0.29	0.19	0.27380952
-25	0.33	0.33	0.48	0.43	0.48	0.43	0.43	0.48	0.33	0.48	0.24	0.38	0.57	0.33	0.29	0.33	0.43	0.29	0.33	0.33	0.38571429
-30	0.57	0.52	0.48	0.38	0.52	0.57	0.33	0.52	0.52	0.57	0.52	0.57	0.43	0.38	0.52	0.48	0.48	0.33	0.38	0.43	0.47619048
-35	0.62	0.43	0.43	0.43	0.52	0.48	0.48	0.52	0.57	0.57	0.43	0.67	0.52	0.38	0.57	0.38	0.43	0.52	0.52	0.43	0.4952381
-40	0.29	0.62	0.38	0.52	0.57	0.52	0.38	0.43	0.43	0.48	0.57	0.48	0.52	0.43	0.48	0.43	0.48	0.43	0.52	0.48	0.47142857
-45	0.57	0.57	0.62	0.43	0.48	0.57	0.67	0.57	0.57	0.48	0.48	0.67	0.52	0.62	0.57	0.52	0.43	0.62	0.62	0.62	0.55952381
-50	0.43	0.57	0.48	0.52	0.52	0.57	0.33	0.71	0.71	0.57	0.62	0.62	0.81	0.48	0.57	0.67	0.43	0.52	0.38	0.71	0.56190476

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