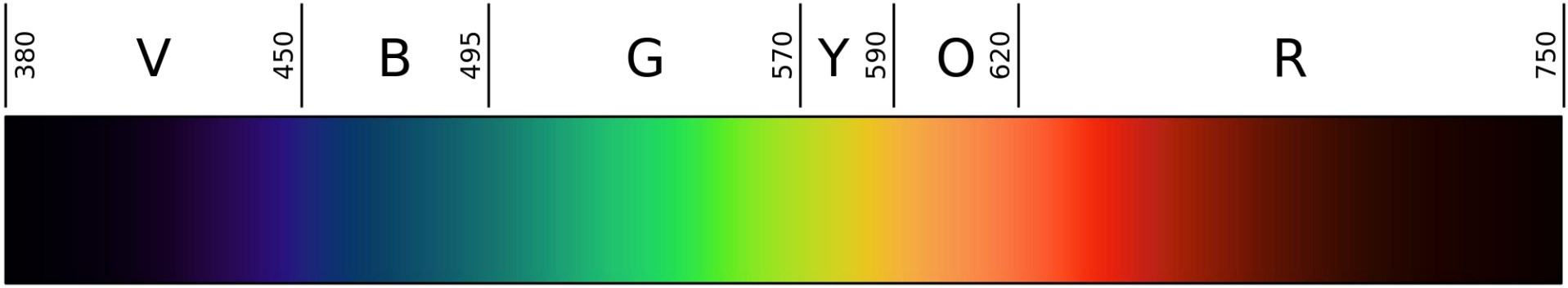


Light wave Communication

Why now is the best time to try it

WF0T & K0XL

352 THz & 476 THz

850nm & 630nm

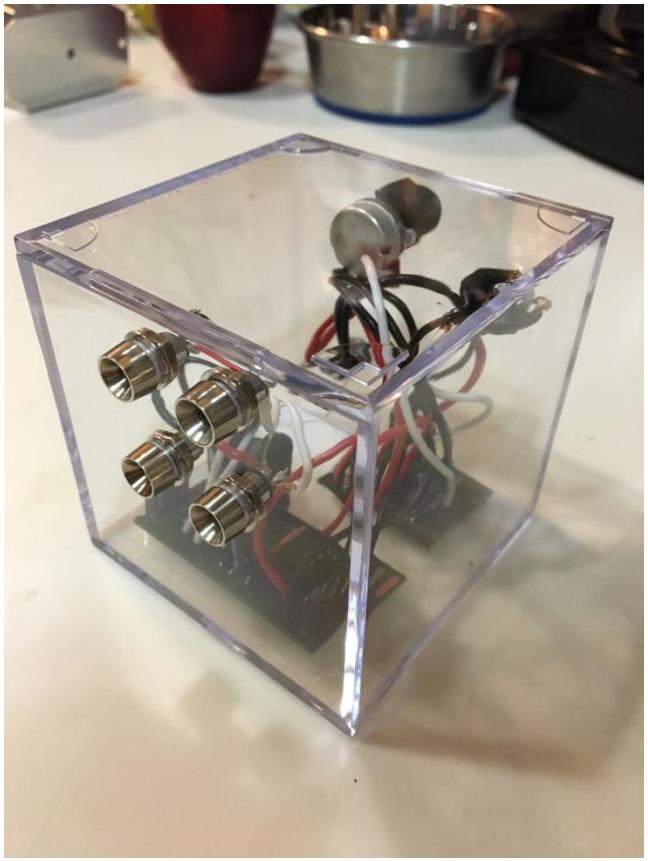
It all started with a Beacon

- 2015
- Digispark ATtiny85 board
- 50% duty cycle
- 4 SFH4550 IR LEDs
- 280mw output
- 352 THz (850nM)

MCW Transmitter

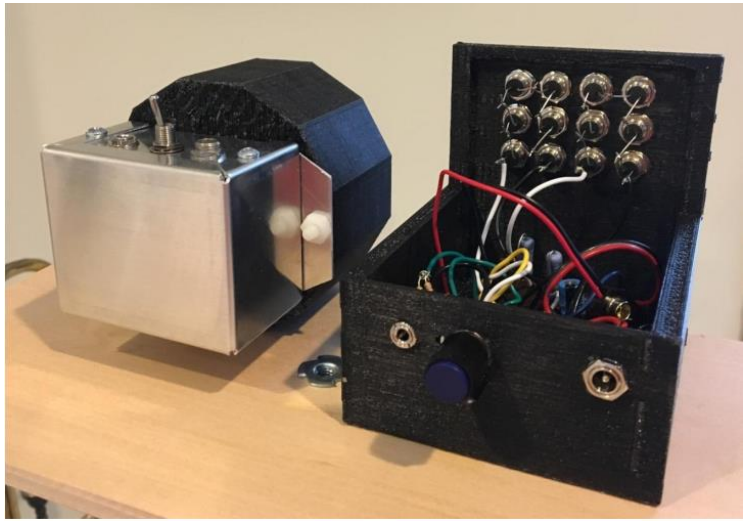
- 2016
- Atmel ATTiny25 chip
- 50% duty cycle
- 1 MSB90TA Red LED
- Radio Shack Jumbo LED
- 16 degree beamwidth
- 200mw output
- 2 modes
  - Beacon
  - Tone for on/off keying

The Baseball

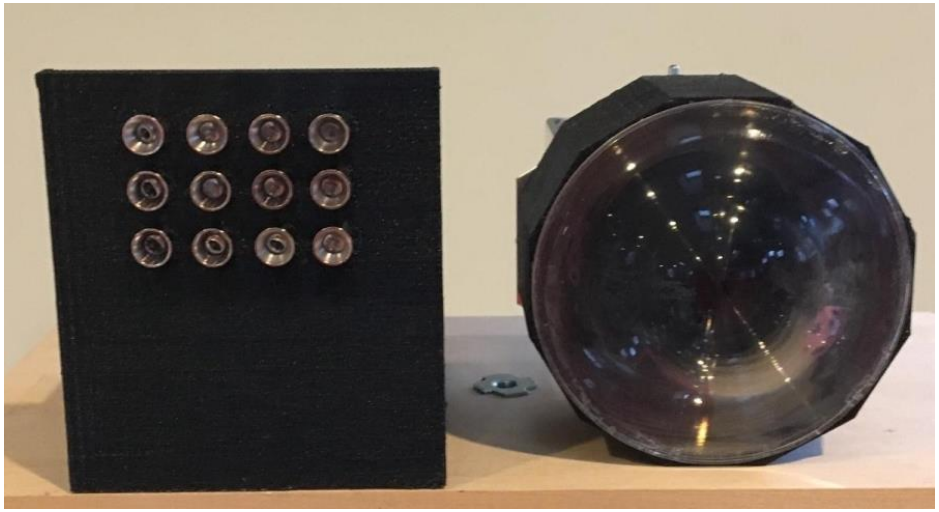


- 2017
- 555 timer PWM
- 30% duty cycle
- LM833 Mic Amp
- 4 SFH4550 IR LEDs
- 750mw output

WF0T Transmitter/Receiver 2018

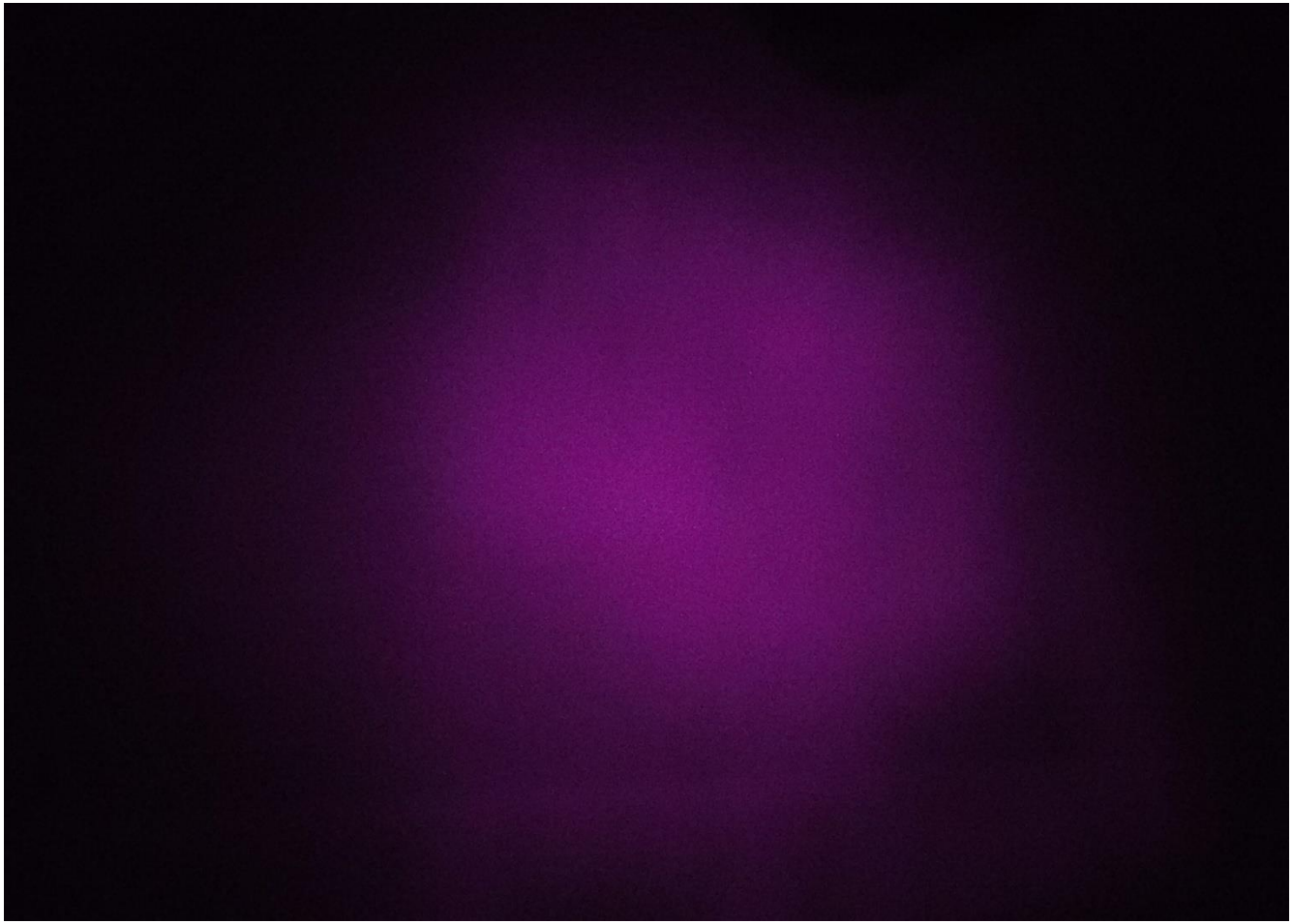


- 3D printed transmitter box
- 555 Timer PWM
- 50% duty cycle
- Audio Amp (LM833 or LM358)
- 12 SFH4550 IR LEDs
- 2 parallel blocks of 6 LEDs in series



- 3D printed lens mount
- 90 mm fresnel lens
- With 50.8 mm focal length
- KA7OEI (K7RJ) v3.1 Receiver

Beam width of 3x4 array

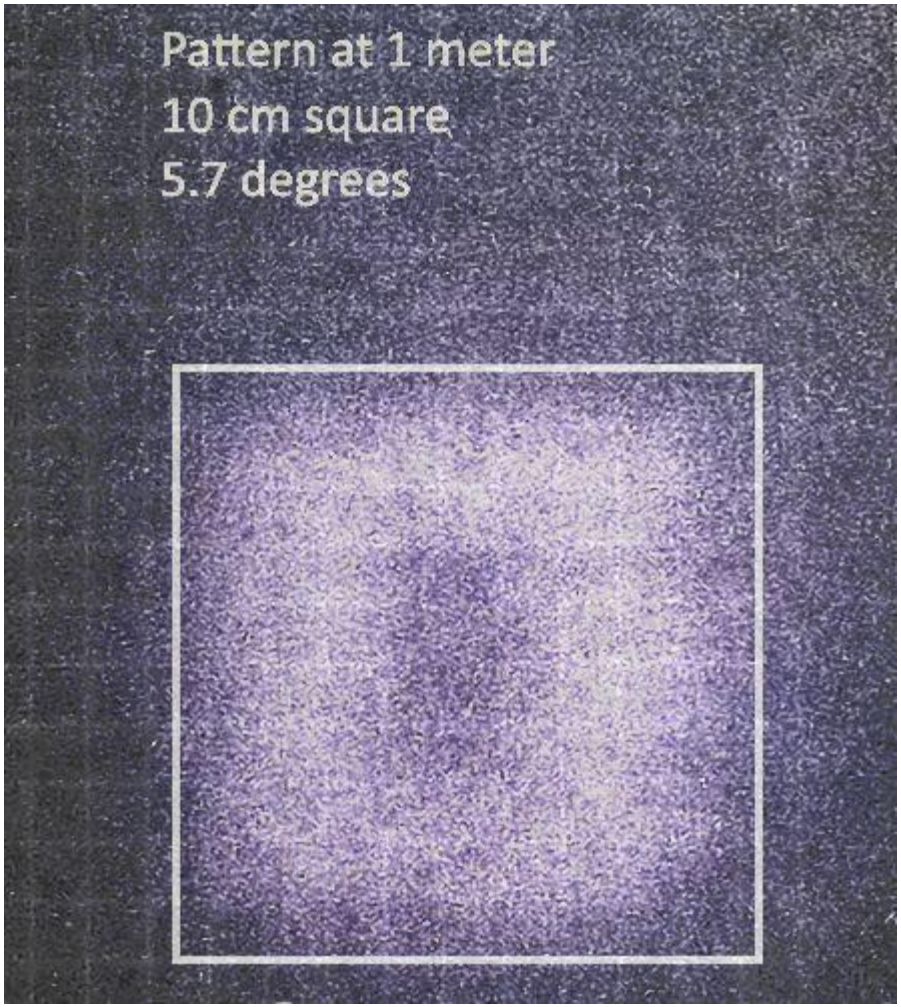


11cm x 13cm

Warren Ferber - WF0T & Rob Jahnke K0XL
(2019)

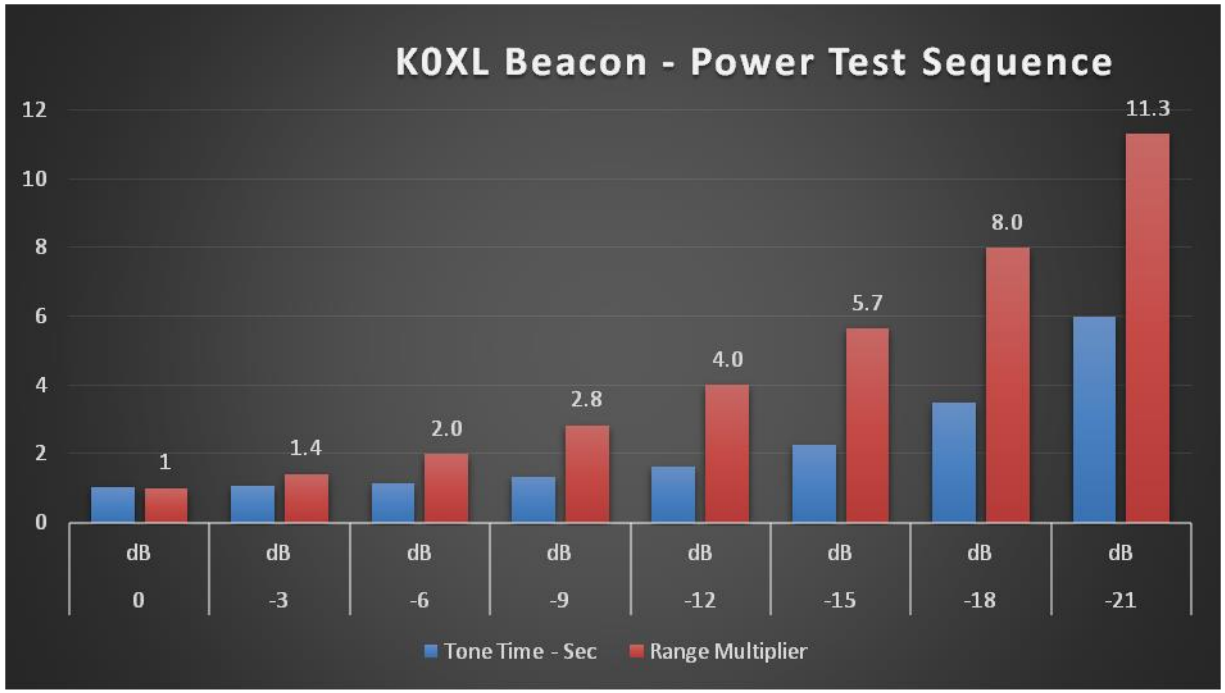
K0XL Optical System 2018

Single LED Flashlight pattern

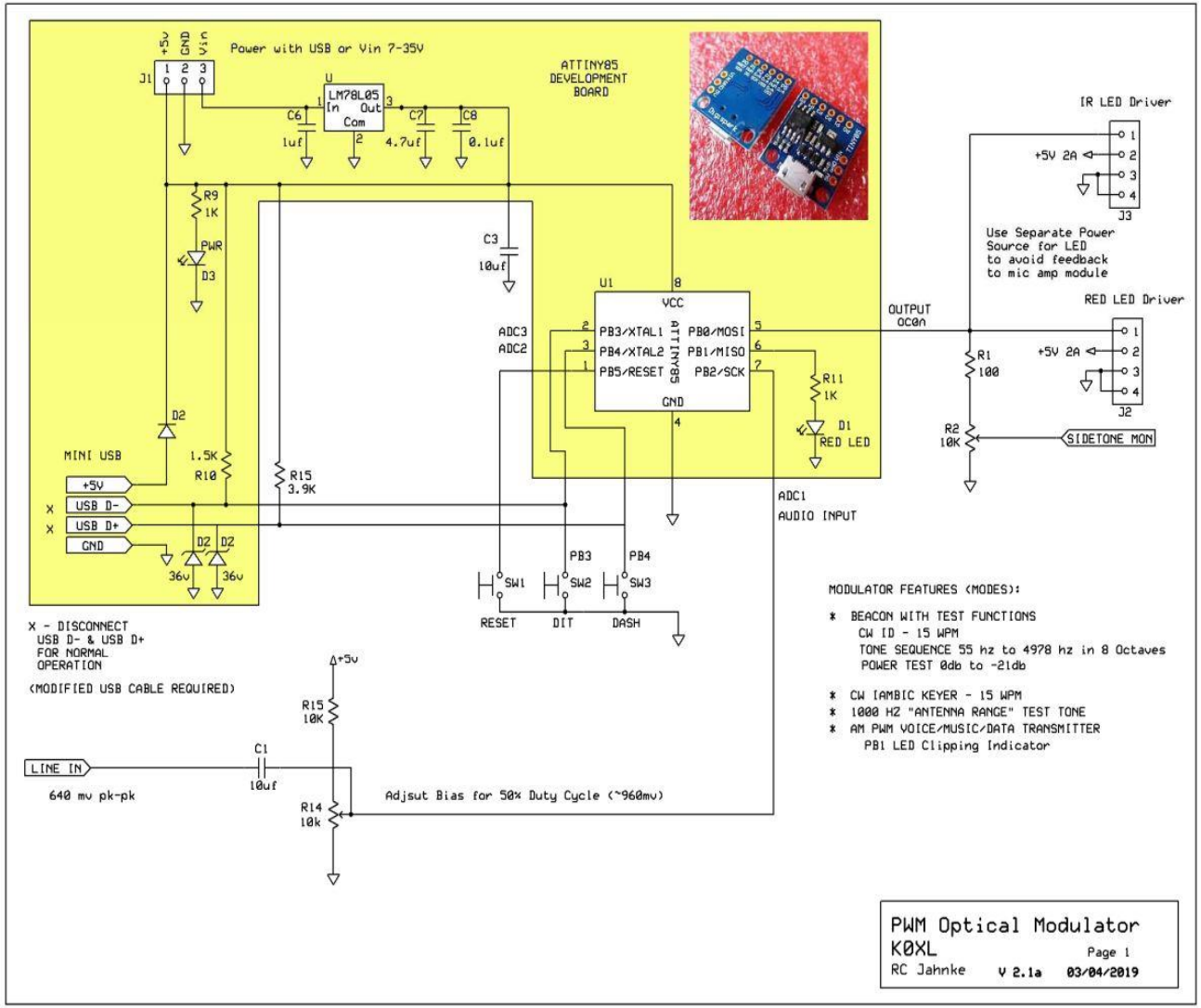


K0XL Beacon

- CW 15wpm “Hello de K0XL/B”
- Tone Test 55, 110, 220, 440, 880, 1760, 3520, 4979, 55 Hz
- Power Sequence



ATTiny85 Beacon - Modulator



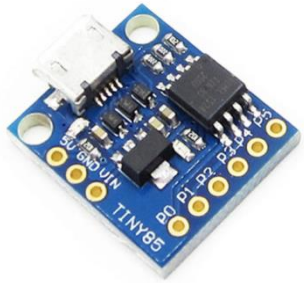
Key Components

$0.70

SFH4550 850nm LED
6 degree beam width
100 ma

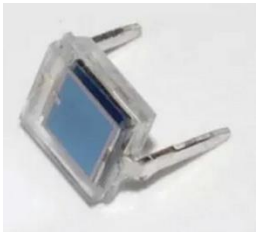
$1

CREE LUXEON 3W
630/850 nm LED
120 degree beam width
1000 ma



$1.50

ATTiny85
“Digispark” board



$1.01

BPW34 Silicon PIN
Diode Detector

$1.11

Atmel ATTiny25
Microcontroller

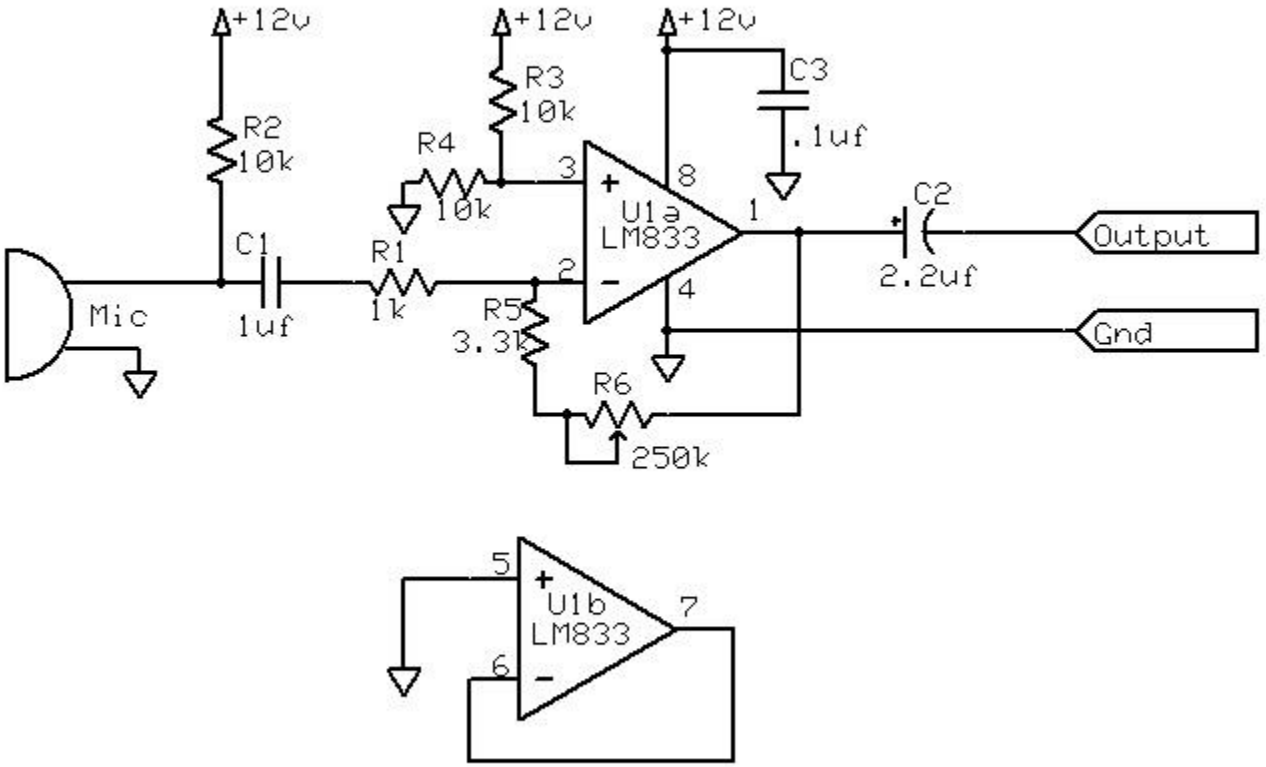
$1.05

Microchip
MCP6021
OpAmp

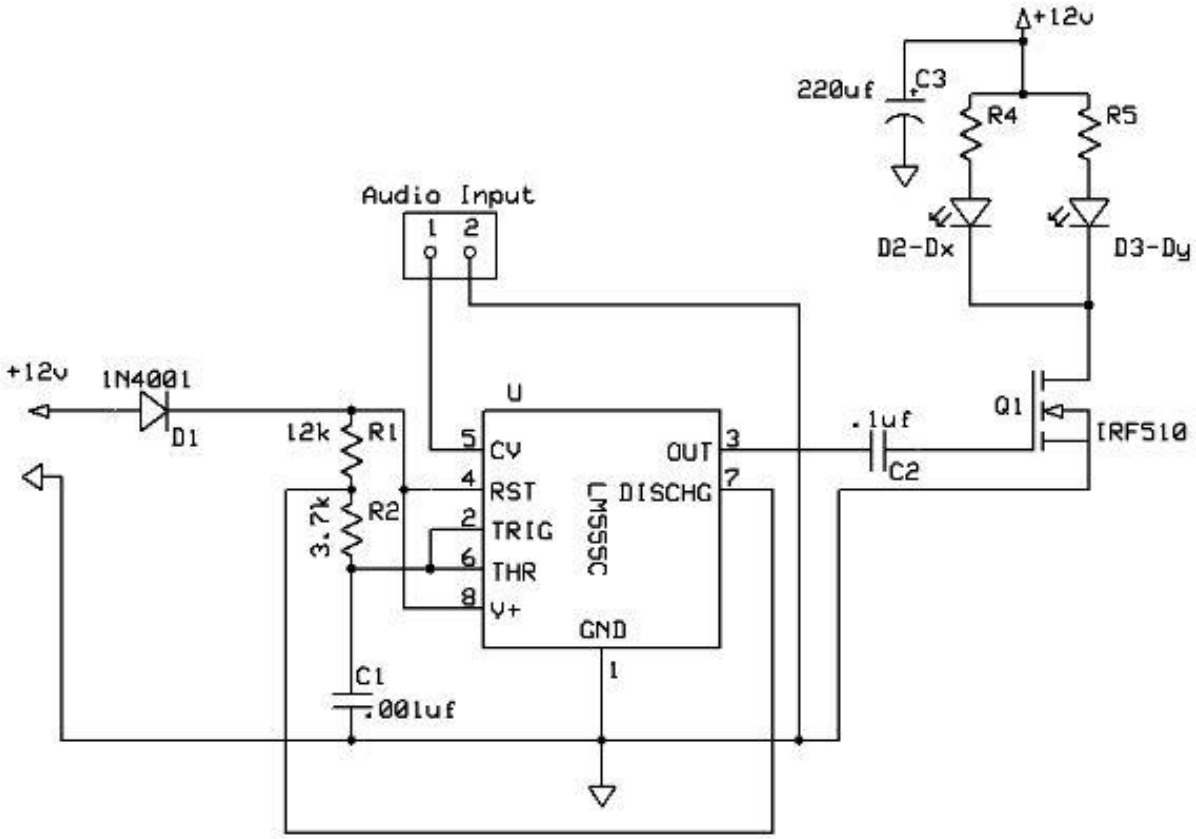
$5 - $10

8.5 x 11
Page Magnifier
320mm Focal length

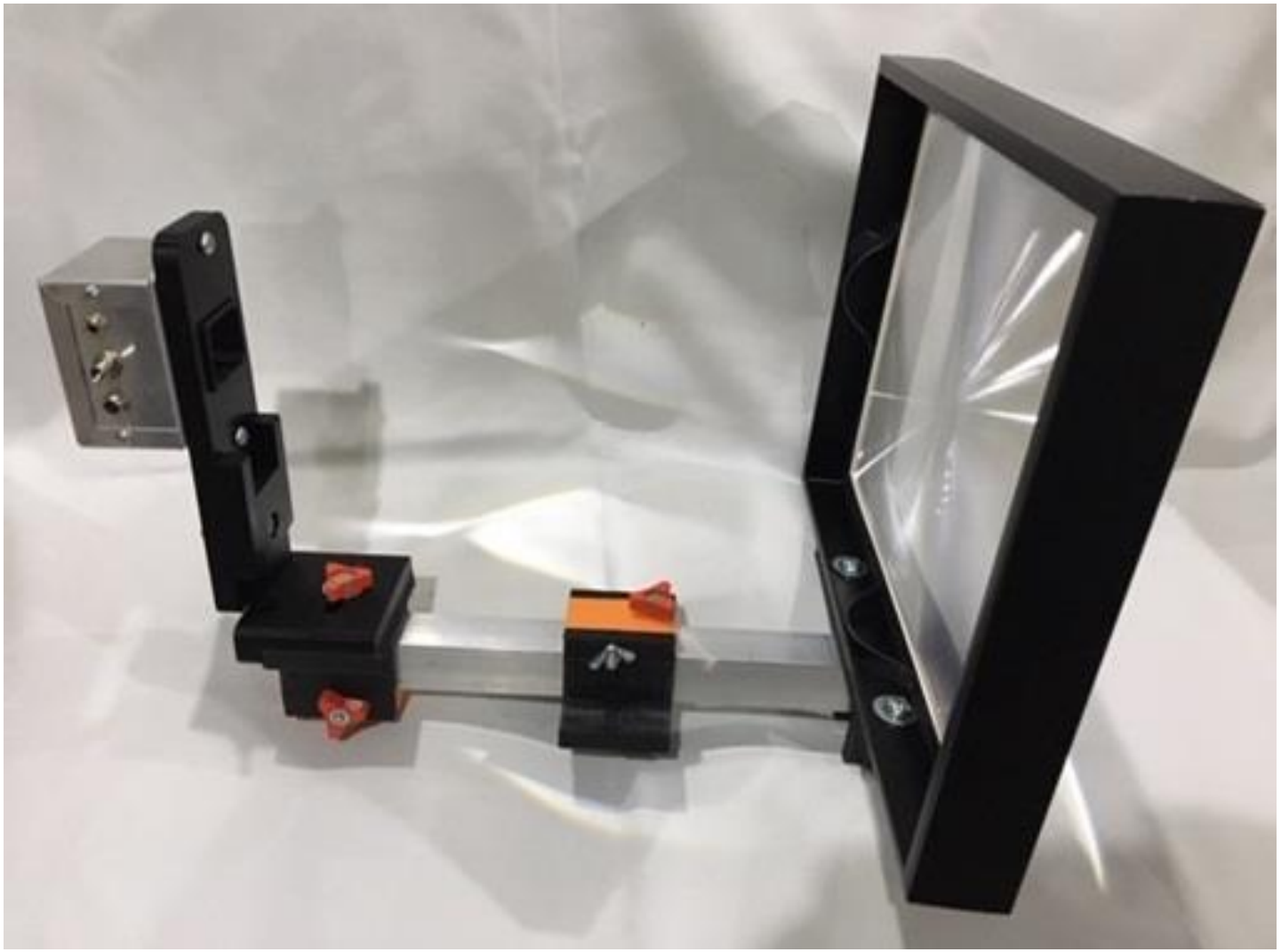
Microphone Amplifier Schematic



LM555 PWM Modulator Schematic

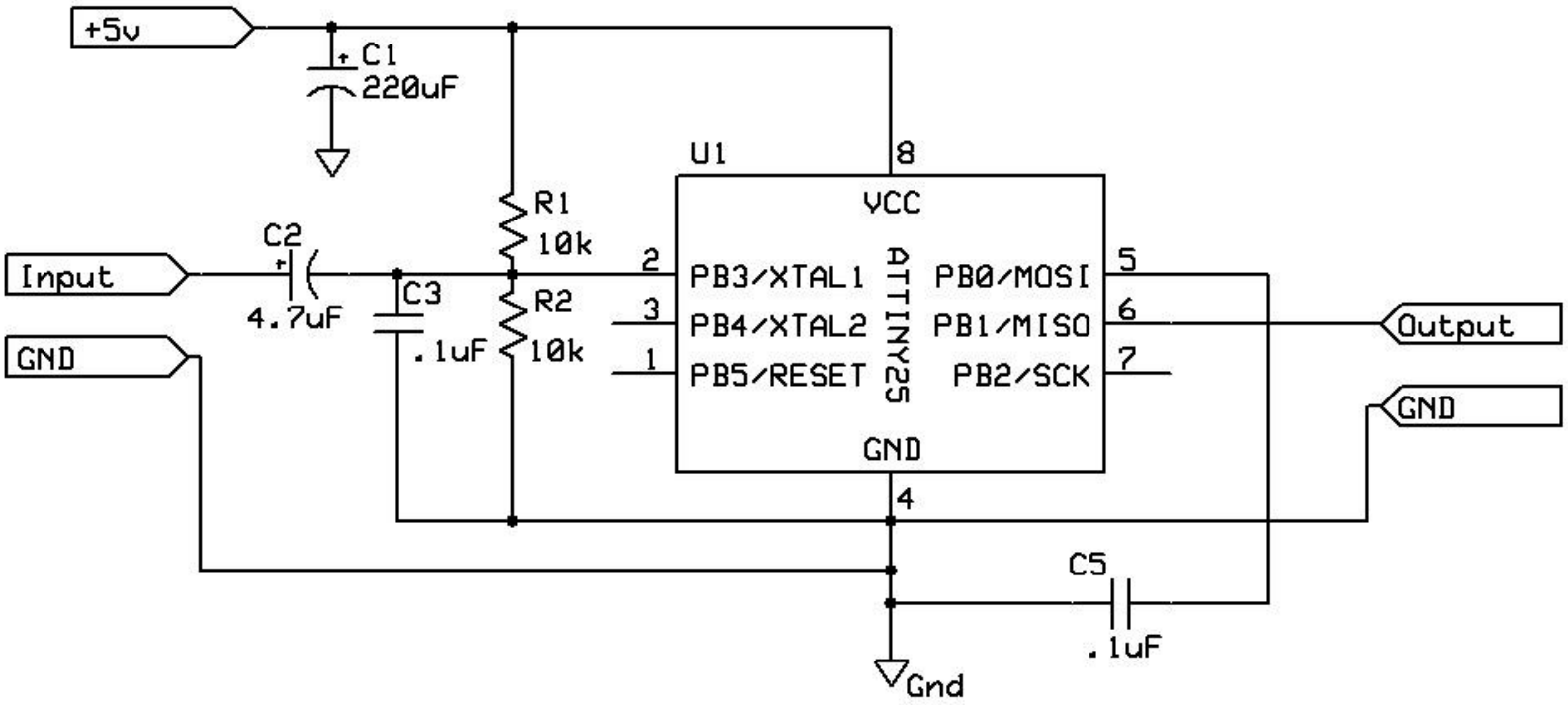


2019

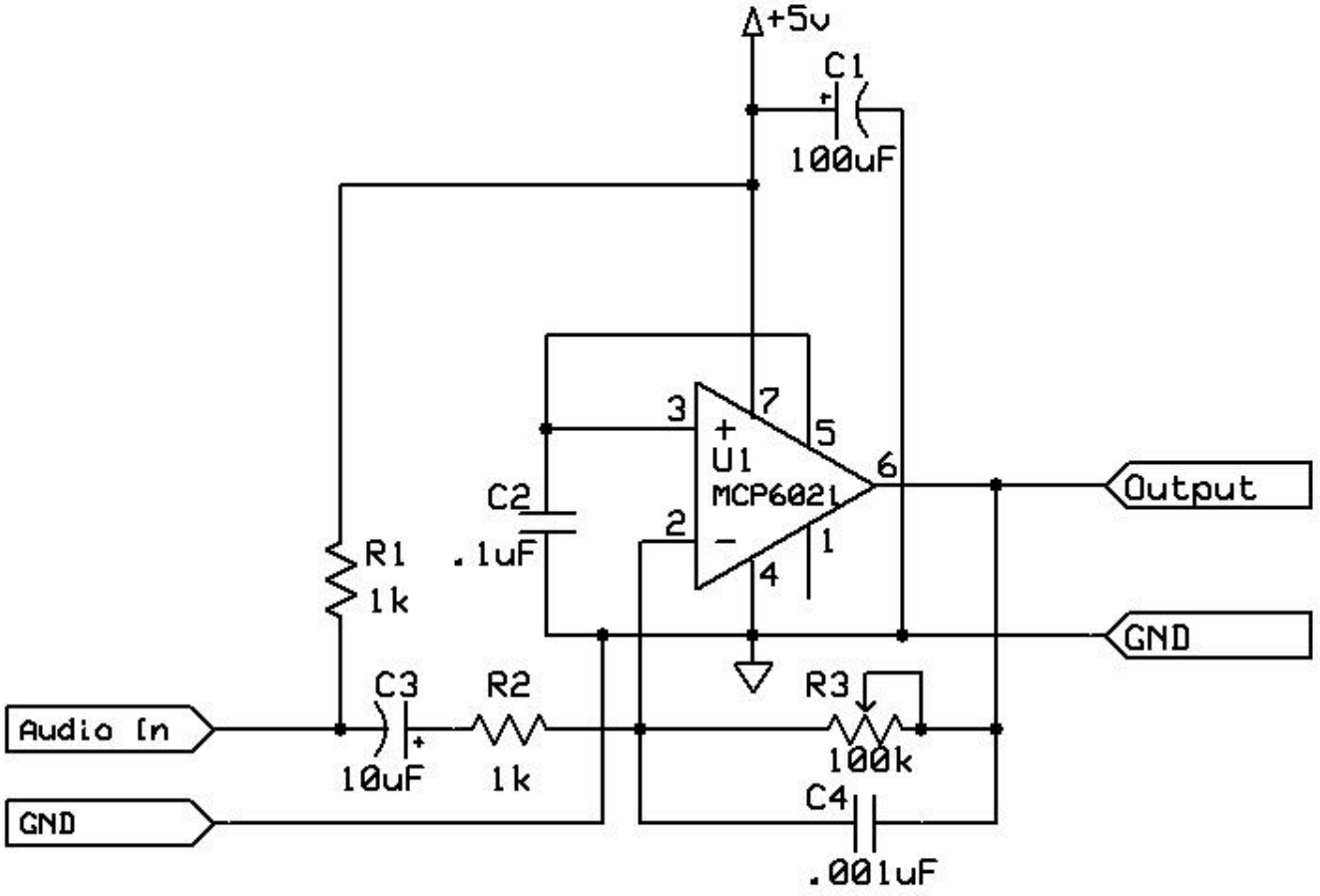


Warren Ferber - WF0T & Rob Jahnke K0XL
(2019)

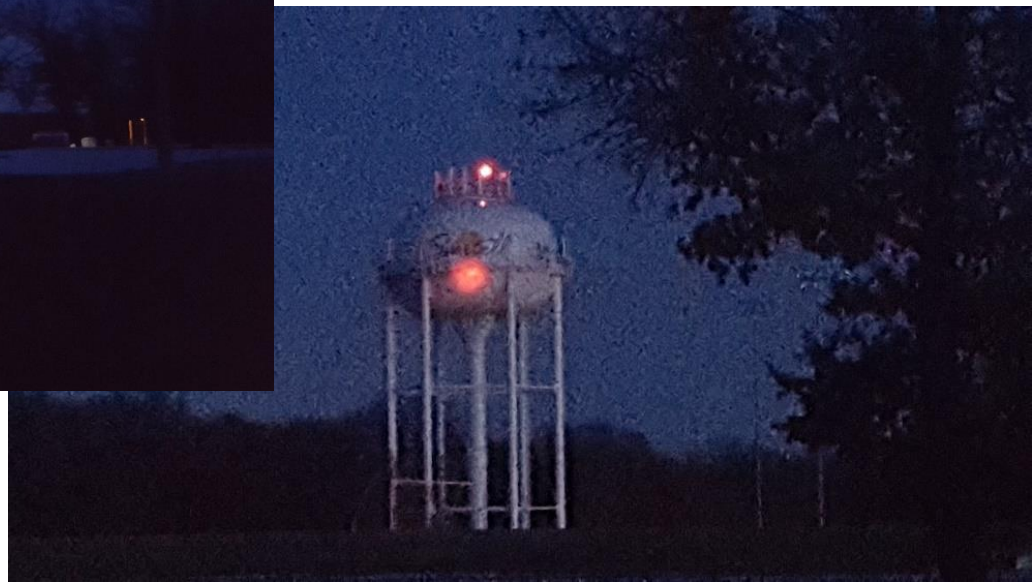
WF0T - ATTiny25 PWM Modulator



New Audio Amp MCP6021



Water Tower Experiments



10ft Square “Spot” on Water Tower

2019 Optical System

Cloud Bounce

Tables of cloud-bounce elevation angles v 1.0, G8AGN 28 Feb 2012

Cloud heights in METAR reports are normally given in feet above ground level

Table of Cloudbounce Elevation Angle in degrees

MILES	5	10	15	20	25	30	35	40	45	50	55	60
FEET												
500	2.2	1.1	0.7	0.5	0.4	0.4	0.3	0.3	0.2	0.2	0.2	0.2
1000	4.3	2.2	1.4	1.1	0.9	0.7	0.6	0.5	0.5	0.4	0.4	0.4
1500	6.5	3.3	2.2	1.6	1.3	1.1	0.9	0.8	0.7	0.7	0.6	0.5
2000	8.6	4.3	2.9	2.2	1.7	1.4	1.2	1.1	1.0	0.9	0.8	0.7
2500	10.7	5.4	3.6	2.7	2.2	1.8	1.5	1.4	1.2	1.1	1.0	0.9
3000	12.8	6.5	4.3	3.3	2.6	2.2	1.9	1.6	1.4	1.3	1.2	1.1
3500	14.9	7.6	5.1	3.8	3.0	2.5	2.2	1.9	1.7	1.5	1.4	1.3
4000	16.9	8.6	5.8	4.3	3.5	2.9	2.5	2.2	1.9	1.7	1.6	1.4
4500	18.8	9.7	6.5	4.9	3.9	3.3	2.8	2.4	2.2	2.0	1.8	1.6
5000	20.7	10.7	7.2	5.4	4.3	3.6	3.1	2.7	2.4	2.2	2.0	1.8
5500	22.6	11.8	7.9	5.9	4.8	4.0	3.4	3.0	2.7	2.4	2.2	2.0
6000	24.4	12.8	8.6	6.5	5.2	4.3	3.7	3.3	2.9	2.6	2.4	2.2
6500	26.2	13.8	9.3	7.0	5.6	4.7	4.0	3.5	3.1	2.8	2.6	2.3
7000	27.9	14.9	10.0	7.6	6.1	5.1	4.3	3.8	3.4	3.0	2.8	2.5
7500	29.6	15.9	10.7	8.1	6.5	5.4	4.6	4.1	3.6	3.3	3.0	2.7
8000	31.2	16.9	11.4	8.6	6.9	5.8	4.9	4.3	3.9	3.5	3.2	2.9
8500	32.8	17.8	12.1	9.1	7.3	6.1	5.3	4.6	4.1	3.7	3.4	3.1
9000	34.3	18.8	12.8	9.7	7.8	6.5	5.6	4.9	4.3	3.9	3.5	3.3
9500	35.7	19.8	13.5	10.2	8.2	6.8	5.9	5.1	4.6	4.1	3.7	3.4
10000	37.1	20.7	14.2	10.7	8.6	7.2	6.2	5.4	4.8	4.3	3.9	3.6

Tables of cloud-bounce elevation angles v 1.0, G8AGN 28 Feb 2012

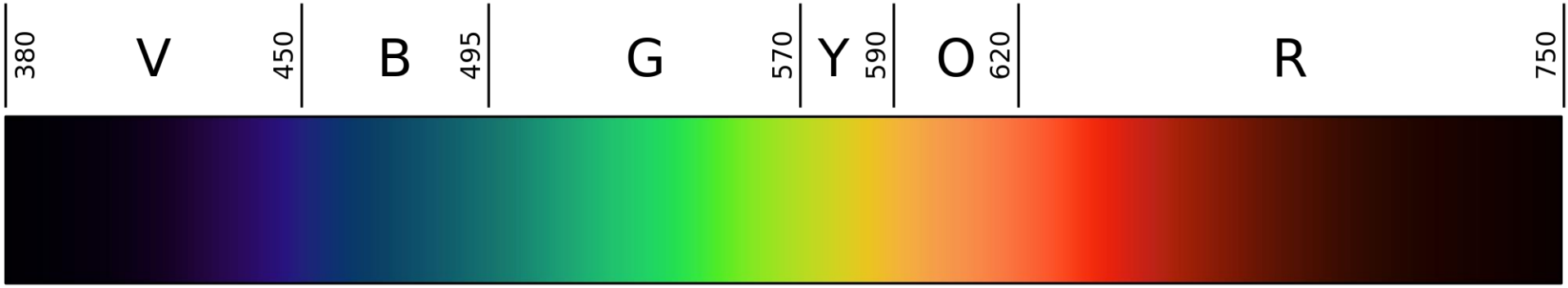
Cloud heights in METAR reports are normally given in feet above ground level

Table of Cloudbounce Elevation Angle in degrees

KM	10	20	30	40	50	60	70	80	90	100	110	120
FEET												
500	1.7	0.9	0.6	0.4	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.1
1000	3.5	1.7	1.2	0.9	0.7	0.6	0.5	0.4	0.4	0.3	0.3	0.3
1500	5.2	2.6	1.7	1.3	1.0	0.9	0.7	0.7	0.6	0.5	0.5	0.4
2000	7.0	3.5	2.3	1.7	1.4	1.2	1.0	0.9	0.8	0.7	0.6	0.6
2500	8.7	4.4	2.9	2.2	1.7	1.5	1.2	1.1	1.0	0.9	0.8	0.7
3000	10.4	5.2	3.5	2.6	2.1	1.7	1.5	1.3	1.2	1.0	1.0	0.9
3500	12.0	6.1	4.1	3.1	2.4	2.0	1.7	1.5	1.4	1.2	1.1	1.0
4000	13.7	7.0	4.6	3.5	2.8	2.3	2.0	1.7	1.6	1.4	1.3	1.2
4500	15.3	7.8	5.2	3.9	3.1	2.6	2.2	2.0	1.7	1.6	1.4	1.3
5000	17.0	8.7	5.8	4.4	3.5	2.9	2.5	2.2	1.9	1.7	1.6	1.5
5500	18.5	9.5	6.4	4.8	3.8	3.2	2.7	2.4	2.1	1.9	1.7	1.6
6000	20.1	10.4	7.0	5.2	4.2	3.5	3.0	2.6	2.3	2.1	1.9	1.7
6500	21.6	11.2	7.5	5.7	4.5	3.8	3.2	2.8	2.5	2.3	2.1	1.9
7000	23.1	12.0	8.1	6.1	4.9	4.1	3.5	3.1	2.7	2.4	2.2	2.0
7500	24.6	12.9	8.7	6.5	5.2	4.4	3.7	3.3	2.9	2.6	2.4	2.2
8000	26.0	13.7	9.2	7.0	5.6	4.6	4.0	3.5	3.1	2.8	2.5	2.3
8500	27.4	14.5	9.8	7.4	5.9	4.9	4.2	3.7	3.3	3.0	2.7	2.5
9000	28.8	15.3	10.4	7.8	6.3	5.2	4.5	3.9	3.5	3.1	2.9	2.6
9500	30.1	16.1	10.9	8.2	6.6	5.5	4.7	4.1	3.7	3.3	3.0	2.8
10000	31.4	17.0	11.5	8.7	7.0	5.8	5.0	4.4	3.9	3.5	3.2	2.9

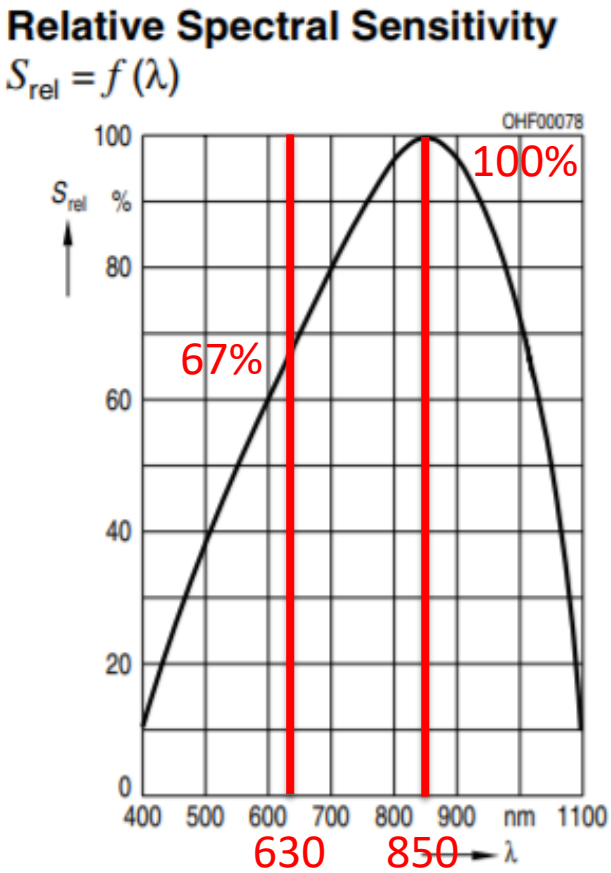
What's Next

- Increase distance to beyond 10 miles
- Continue experiments with cloud bounce and atmospheric scatter
- Introduce the Optical Rail System to more hams
- Build more units
- Get more results published
- Learn more about what is possible using light
- Build daylight tolerant receiver
  - transimpedence amplifier circuit

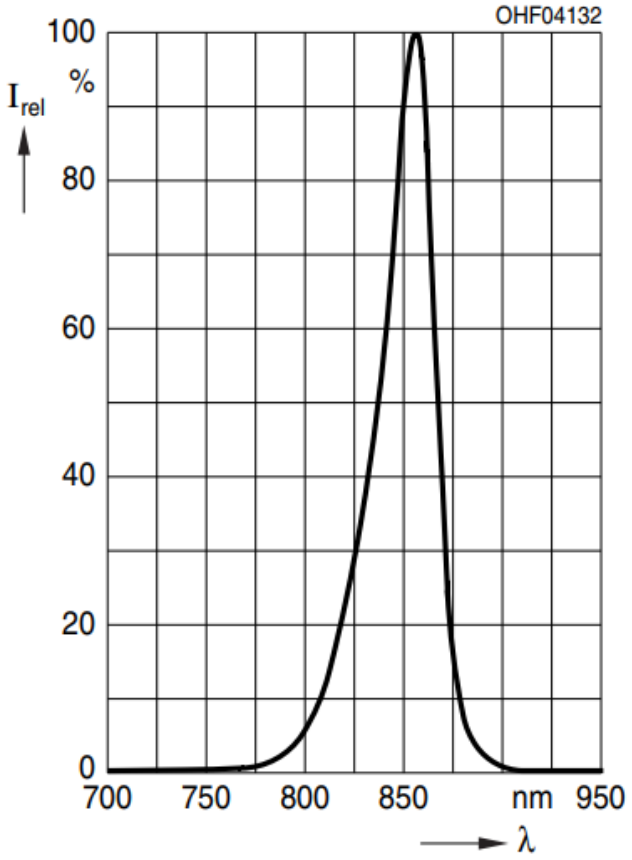


Appendix

BPW34 Sensor & SFH4550 LED



BPW34 Silicon PIN Diode Detector

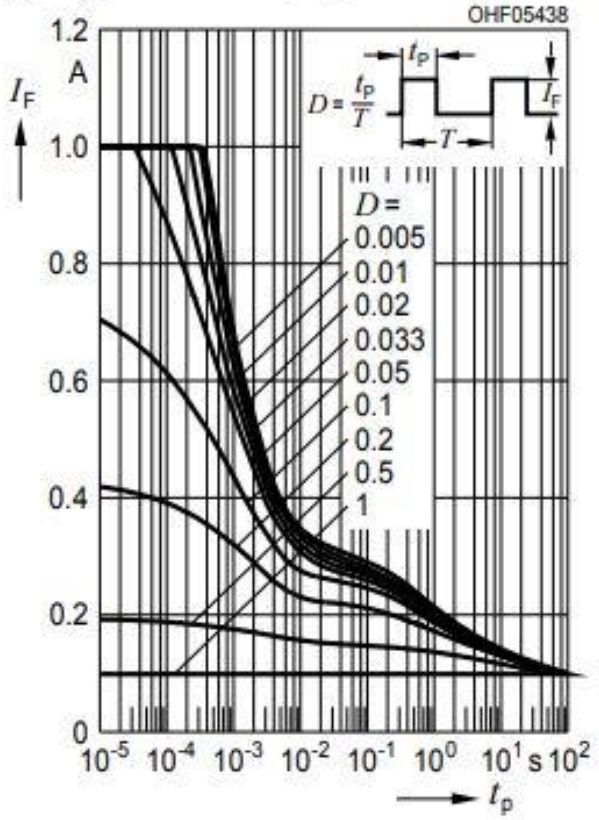


SFH4550 IR LED

SFH4550 Datasheet excerpts

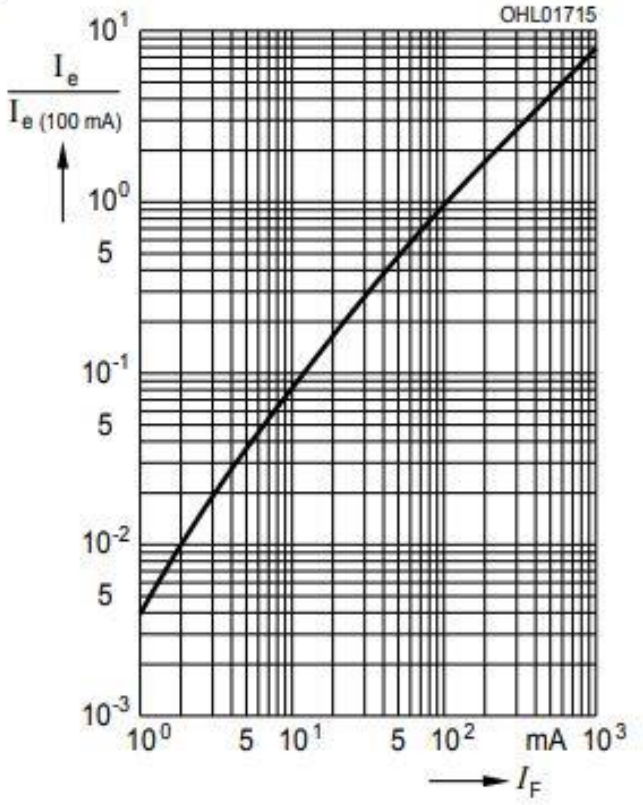
Permissible Pulse Handling Capability

$I_F = f(t_p)$, T_A = 25 °C, duty cycle D = parameter

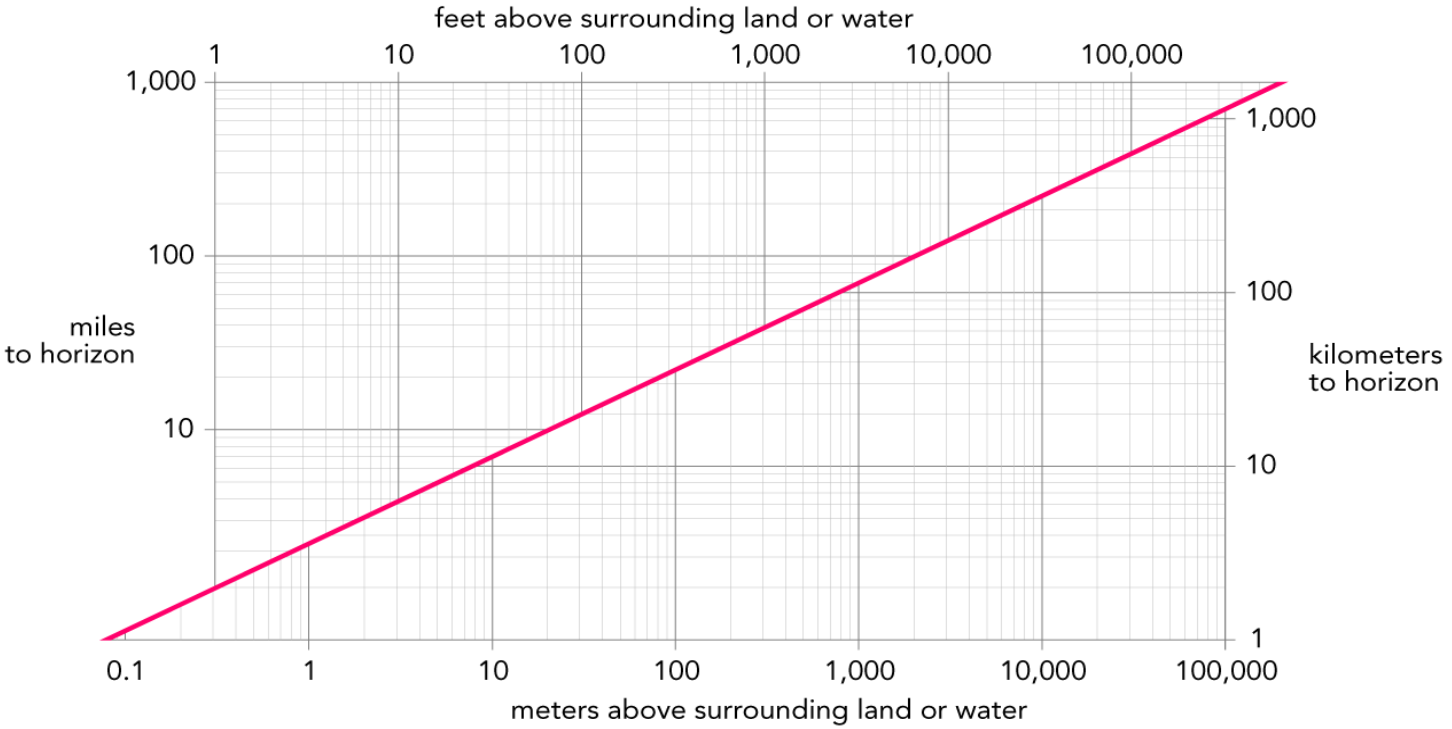


Radiant Intensity 2) *page 8*

$I_e / I_e(100\ mA) = f(I_F)$, single pulse, t_p = 25 µs, T_A= 25°C



How far away is the horizon?



How to calculate?

First, remember that at 6 feet, the horizon is almost exactly 3 miles away. At 2 meters, it is about 5 km away.
Second, if your height increases by a factor of x, the distance to the horizon increases by factor of $\sqrt{x}$ (for any units).
So if your eyes are at an elevation of 24 feet, the horizon is 6 miles away. At 200 meters, it is 50 km away.
These easy-to-calculate values are accurate to about 1% for all elevations on this chart.
(At higher elevations, the straight-through-the-air distance and the along-the-curved-earth distance both begin to diverge from this power-law relationship.)

Warren Ferber - WF0T & Rob Jahnke K0XL
(2019)

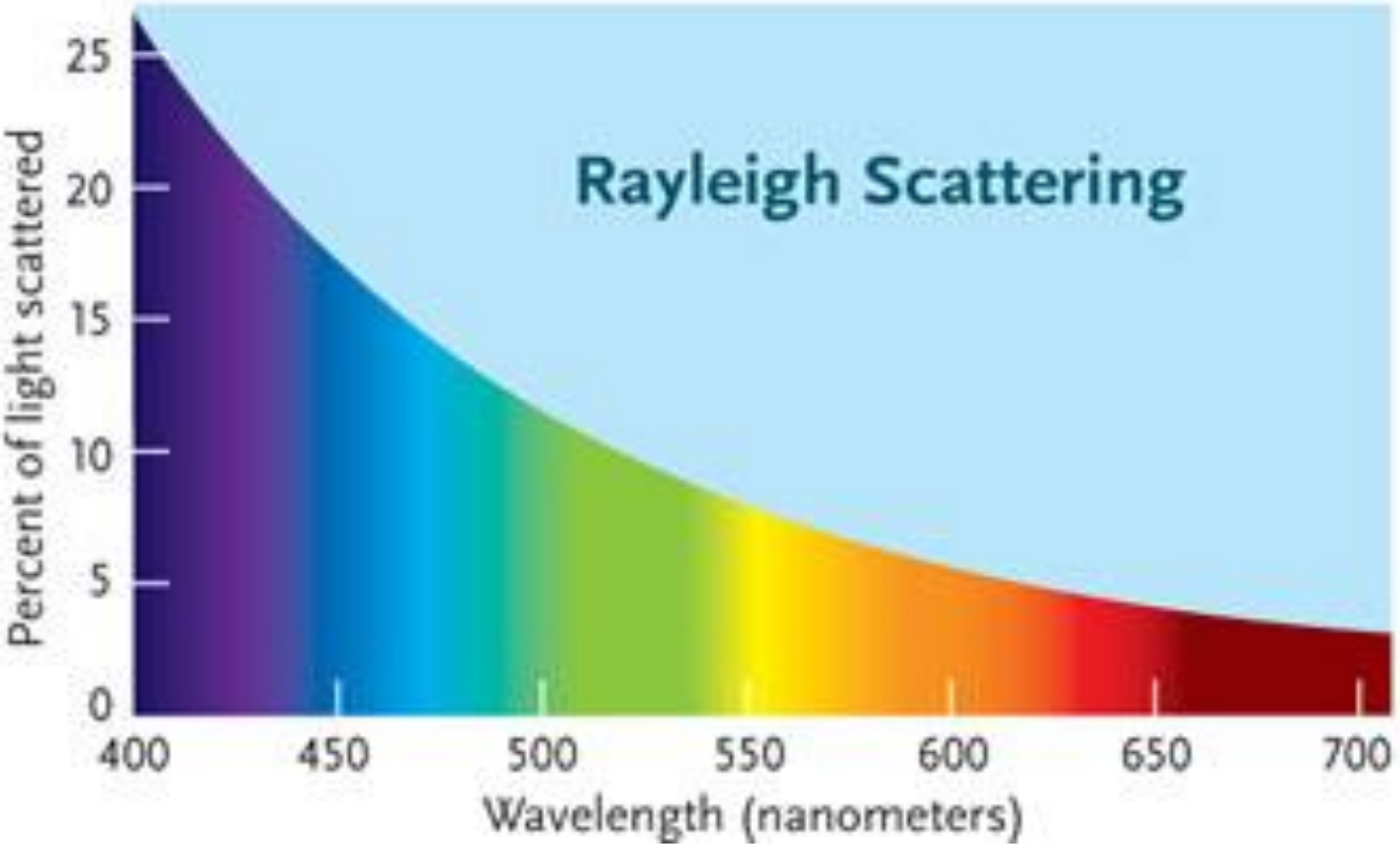
Determining Cloud Cover

Current Weather

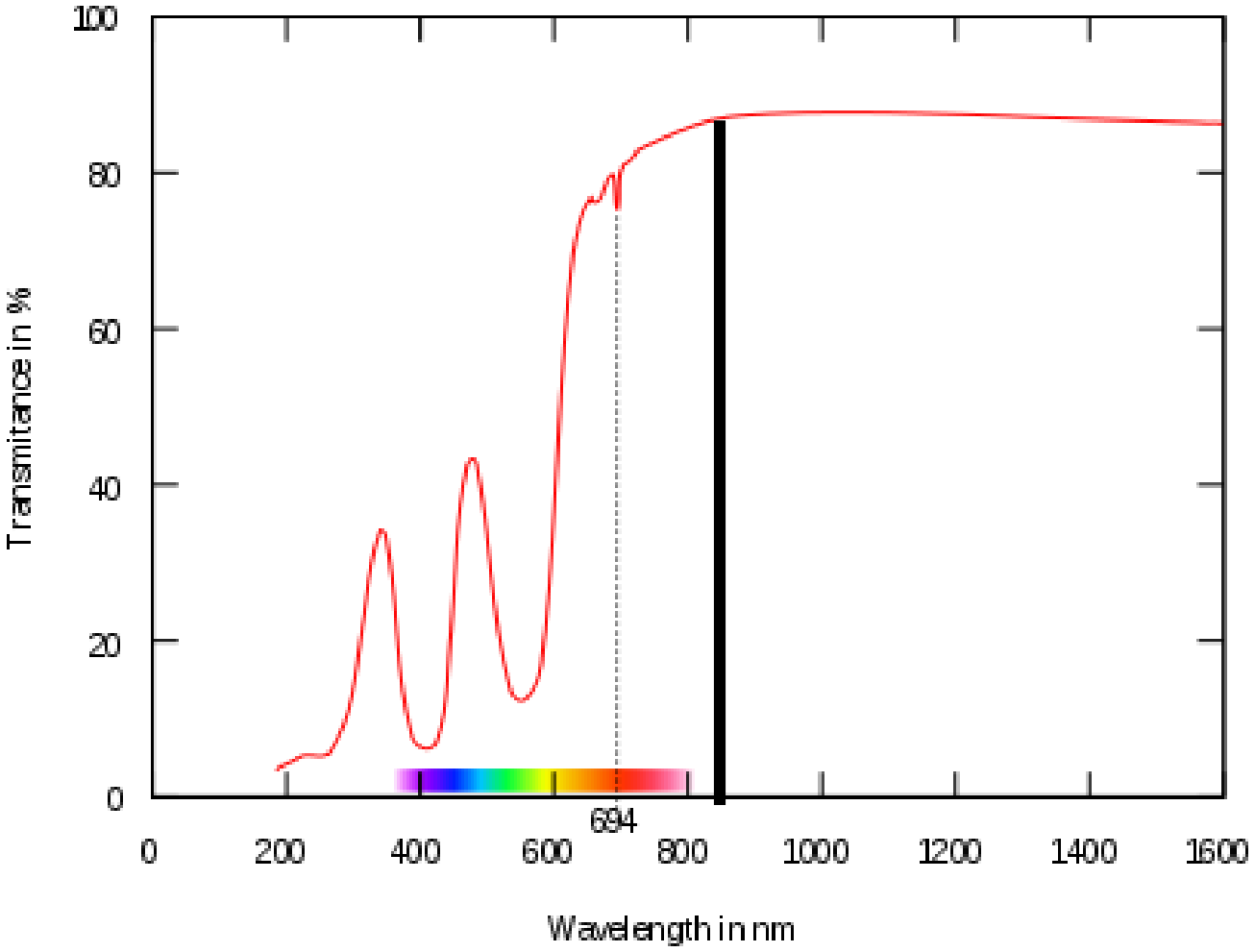
METAR	Observed
KMSP 180053Z 15007KT 10SM FEW070 BKN110 BKN300 24/09 A3023	Mon, Apr 18, 2016 @ 00:53 UTC (1 Hour, 1 Minute ago)

Wind	Visibility	Clouds
150° at 7 knots (8 mph)	10 statute miles	Few at 7,000 ft AGL Broken at 11,000 ft AGL Broken at 30,000 ft AGL

Source: http://www.checkwx.com/weather/KMSP



Source: Sky & Telescope illustration, June 10, 2008



By FDominec - self-made using Gnuplot, GFDL, https://commons.wikimedia.org/w/index.php?curid=3754830

WF0T ATTinyx5 Modulator code

```
//////////////////////////////////////////////////////////////
// Working ADC over PWM.  ADC input on PB3 (Pin 2)
// PWM output on PB1 (Pin 6)
// Vcc/2 bias on ADC input with .01uf cap from ADC input to GND
// 15pf cap and 560 ohm resistor in series after vcc/2 to ADC input
// WF0T - Warren Ferber, February 12, 2019
// ATTinyX5 chip
// Code protected under Creative Commons Attribute license
//////////////////////////////////////////////////////////////

void adc_setup()
{
 // Set the ADC input to PB3 (ADC3 on pin 2)| Reference voltage Vcc
 ADMUX = 1 << ADLAR | 1 << MUX0 | 1 << MUX1 | 0 << REFS0 | 0 <<
       REFS1;
 // Set ADEN to enable ADC and ADPSx for prescaler divide by 64
 ADCSRA = 1 << ADEN | 1 << ADPS1 | 1 << ADPS2;
}

void pwm_setup()
{
   // Set PWM output to PB1 (pin 6)
 DDRB = _BV(PB1);

 // Enable 64 MHz PLL and use as source for Timer1
 PLLCSR = 1 << PCKE | 1 << PLLE;

// Timer interrupts OFF
 TIMSK = 0;

//NEW Jan 3, 2019 - Enable PWM A, Clock selection 47 KHz, Clear the OC1A
//output line on compare match
 TCCR1 = 1 << PWM1A | 1 << CS12 | 1 << COM1A1; // | 1 << CS10;
 //Sets resolution of the OCR1C register to 7.4 bits - estimate
 OCR1C = 165;
 OCR1A = 255;
}
// Functions: adc_read and pwm_write
byte adc_read (void)
{

  // Start the conversion
   ADCSRA |= (1 << ADSC);
   // Wait for it to finish
   while (ADCSRA & (1 << ADSC));

   // 8 bit ADC Value
   return ADCH;
}
void pwm_write (byte val)
{
   OCR1A = val;
}
int main(void)
{
 volatile byte adc_in;
 adc_setup();
 pwm_setup();
 while(1)
 {
   adc_in = adc_read();
   pwm_write(adc_in);
 }
}
```

Resources

- WF0T Blog on Light Communication experiments
  - http://wf0t.blogspot.com
- K0XL Google Site – 3D part files, build pictures, Arduino code for modulators
  - https://sites.google.com/view/k0xl
- KA7OEI Optical Communications website
  - http://www.modulatedlight.org/optical_comms/optical_index.html
- G3XBM Blog
  - http://g3xbm-qrp.blogspot.com/2013/03/k3pgp-optical-receiver-optimised.html
- DigiKey - MN based electronic parts
  - http://www.digikey.com
- Cloud cover reports – Aviation Weather Center & CheckWx.com
  - https://aviationweather.gov/metar
  - http://www.checkwx.com/weather