WiFi Based Wireless Imaging and Positioning for WSN

371-20-06

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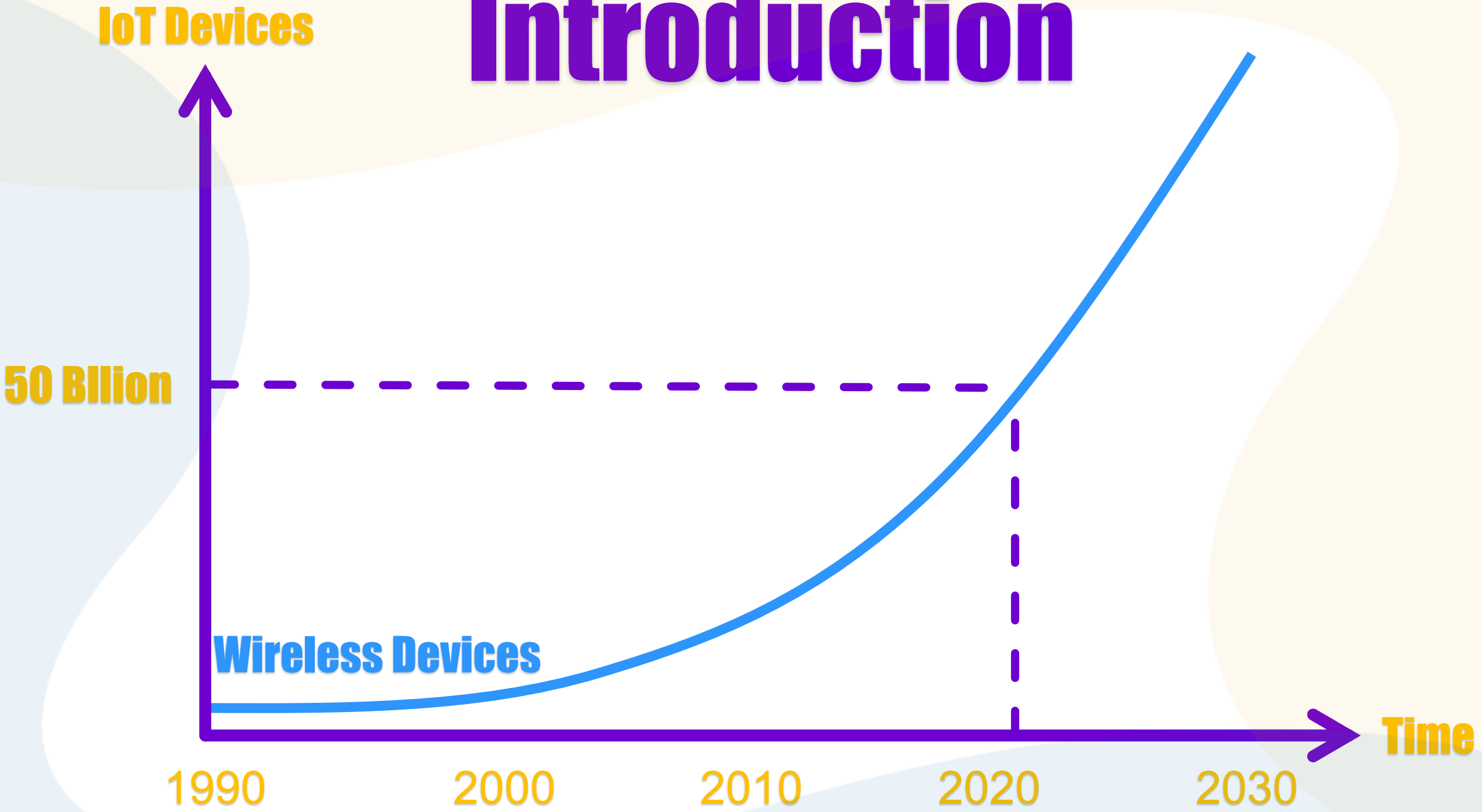
Introduction



Objectives

- Gain info from Radio Signals
  - Image a room using radio signals
- Gain info from the WiFi Protocol
  - Triangulate the position of the sensor

WiFi Protocol

Control and Provisioning of Wireless Access Points

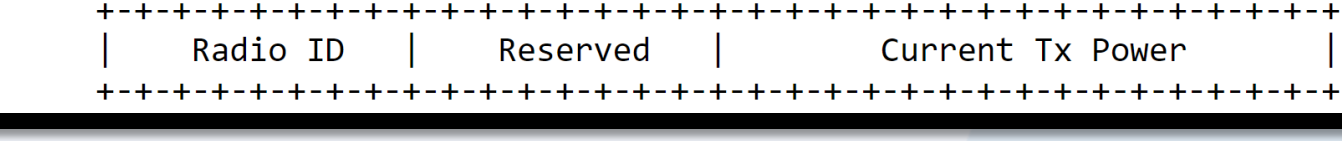
RFC 5416

Tx Power

Beacon frame

Contains all the information about the network and is transmitted periodically.

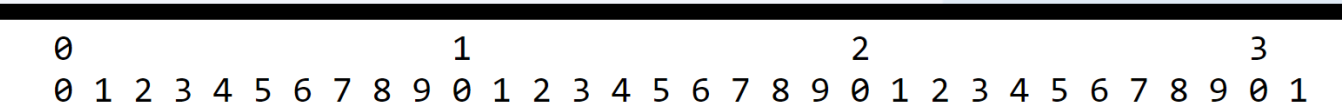
The IEEE 802.11 Tx Power message element value is bi-directional. When sent by the WTP, it contains the current power level of the radio in question. When sent by the AC, it contains the power level to which the WTP MUST adhere.



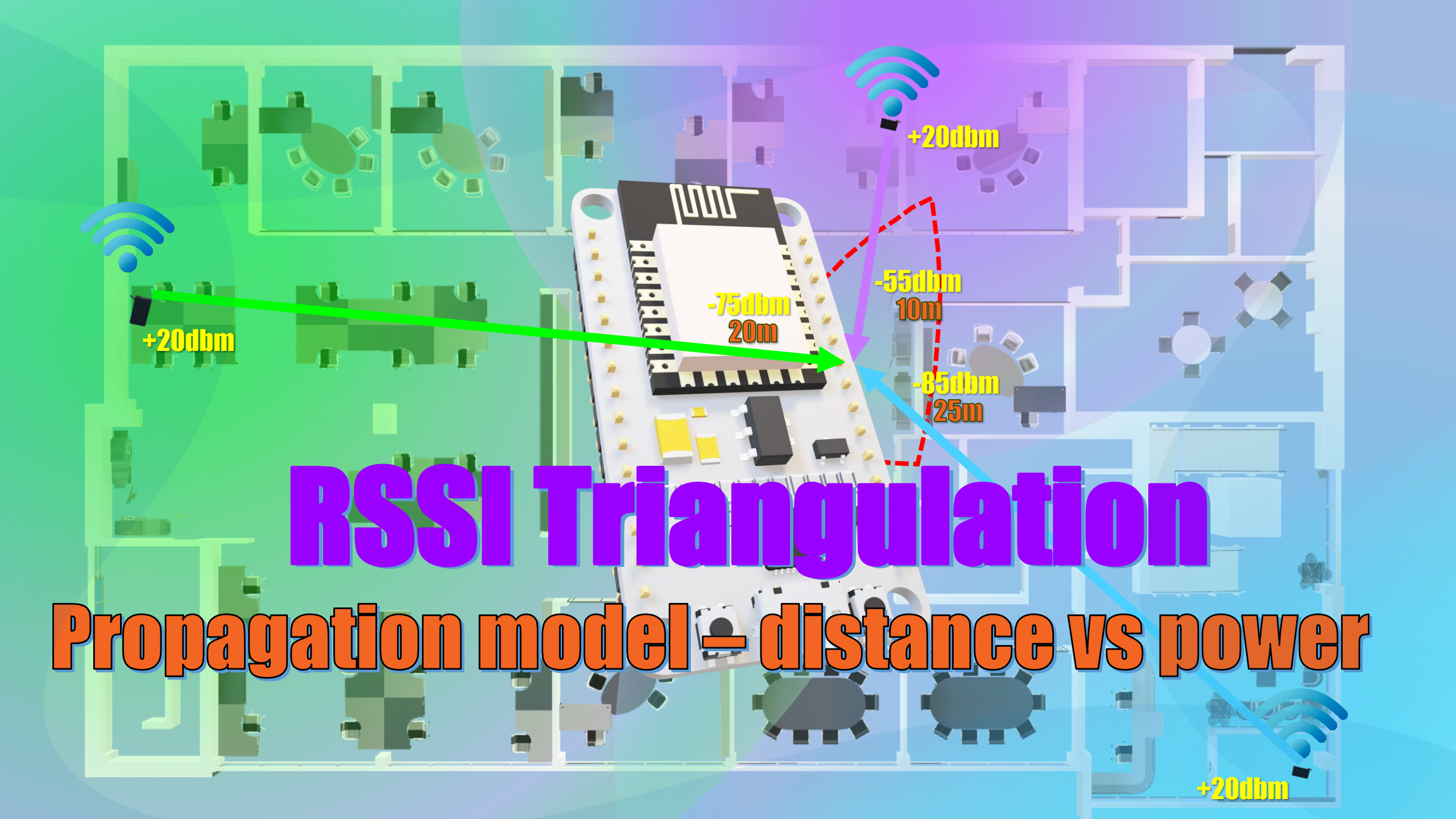
RSSI

Received Signal Strength Indicator

An indication of the power level being received by the receiving radio after the antenna and possible cable loss. The greater the RSSI value, the stronger the signal.



RSSI: Received Signal Strength Indication (RSSI) is a signed, 8-bit value. It is the received signal strength indication, in dBm.



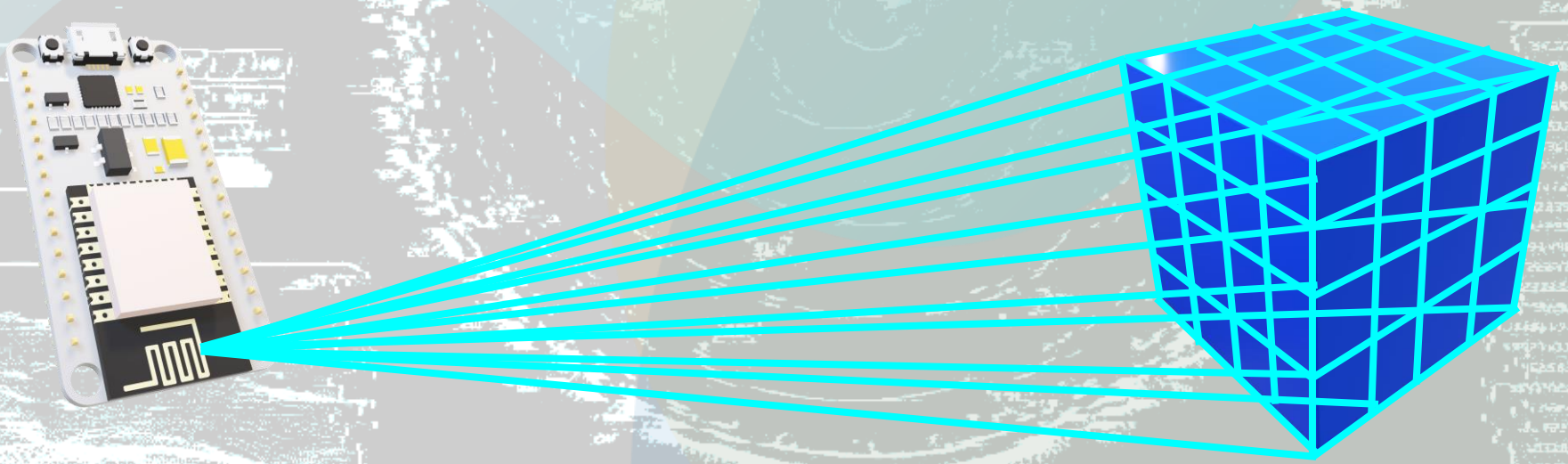
RSSI Triangulation

Propagation model – distance vs power

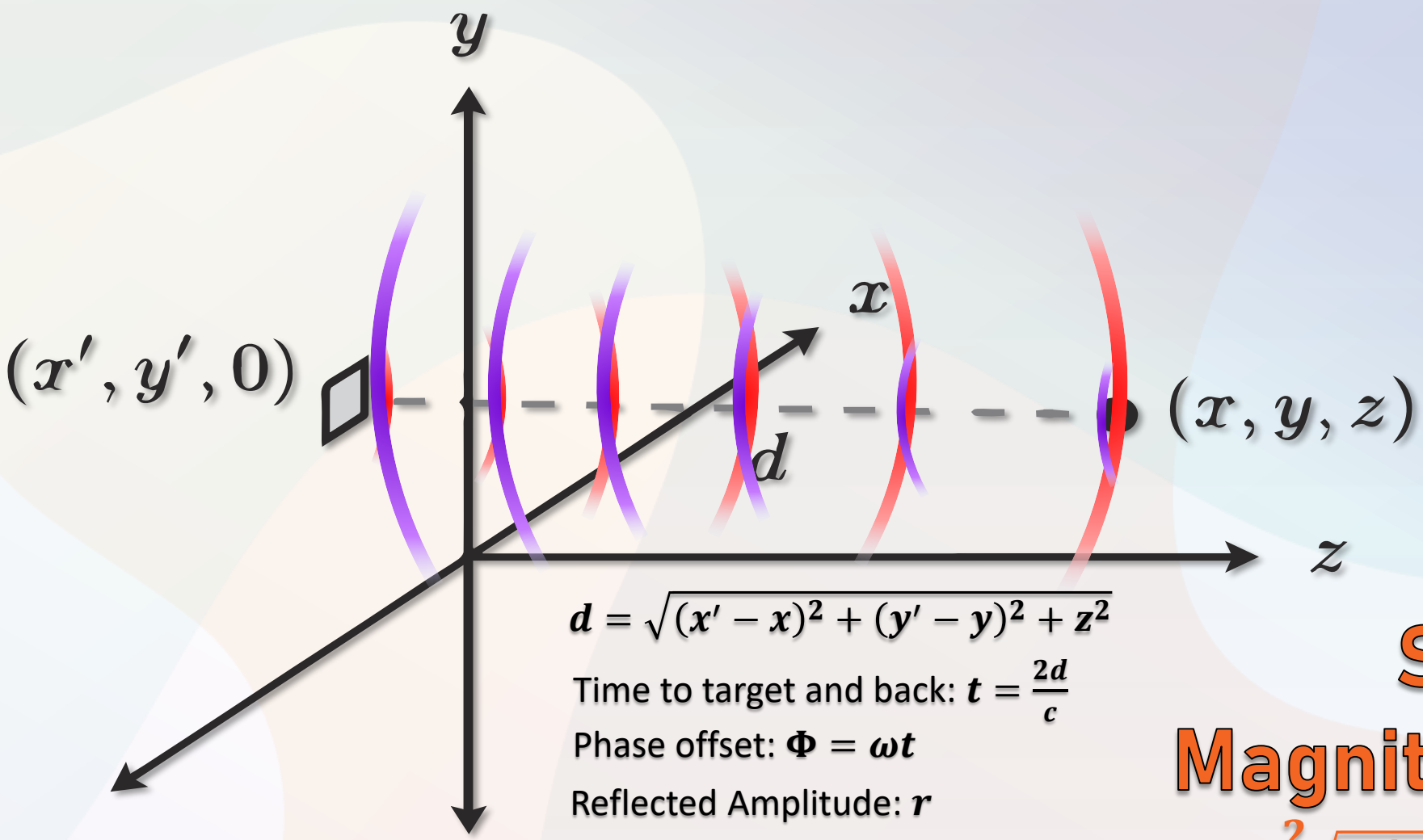
Radio Detection and Ranging

Using radio waves to determine the range, angle, or velocity of objects.

Synthetic-Aperture Radar



RANGE MIGRATION ALGORITHM



Emitted signal

Reflected signal

$$d = \sqrt{(x' - x)^2 + (y' - y)^2 + z^2}$$

Time to target and back: $t = \frac{2d}{c}$

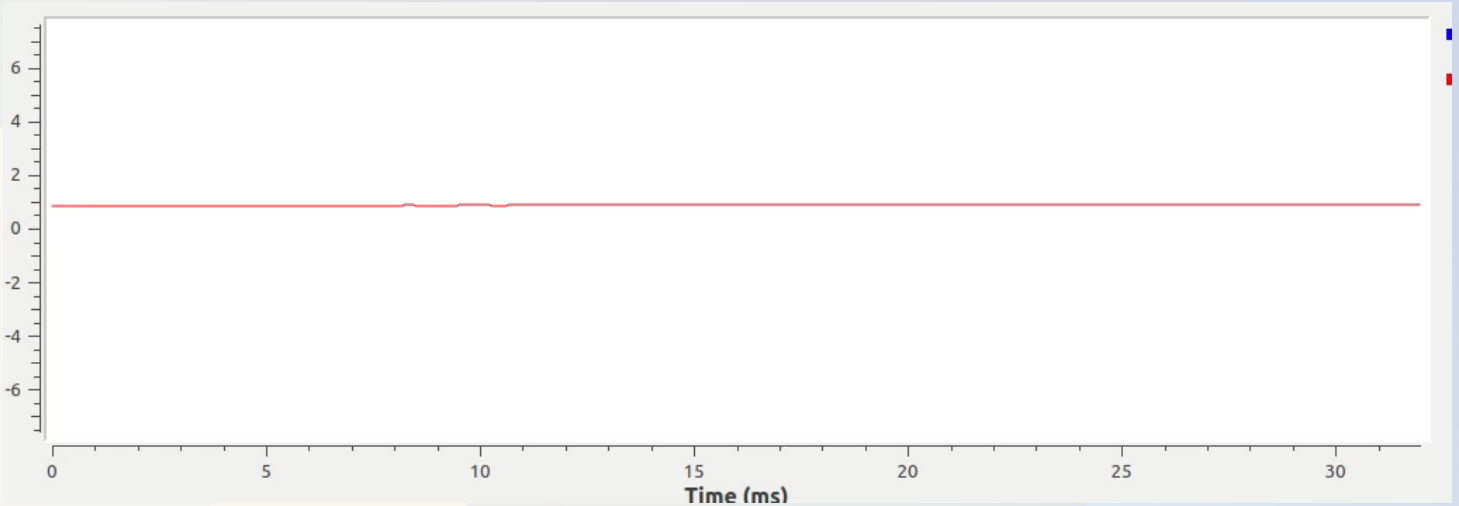
Phase offset: $\Phi = \omega t$

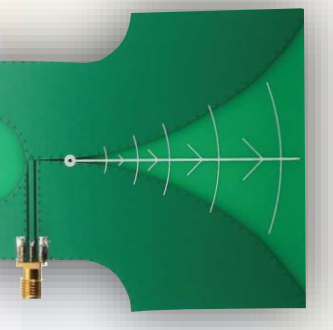
Reflected Amplitude: r

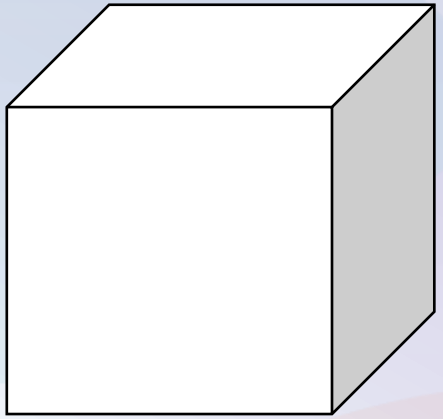
Sample Magnitude & Phase

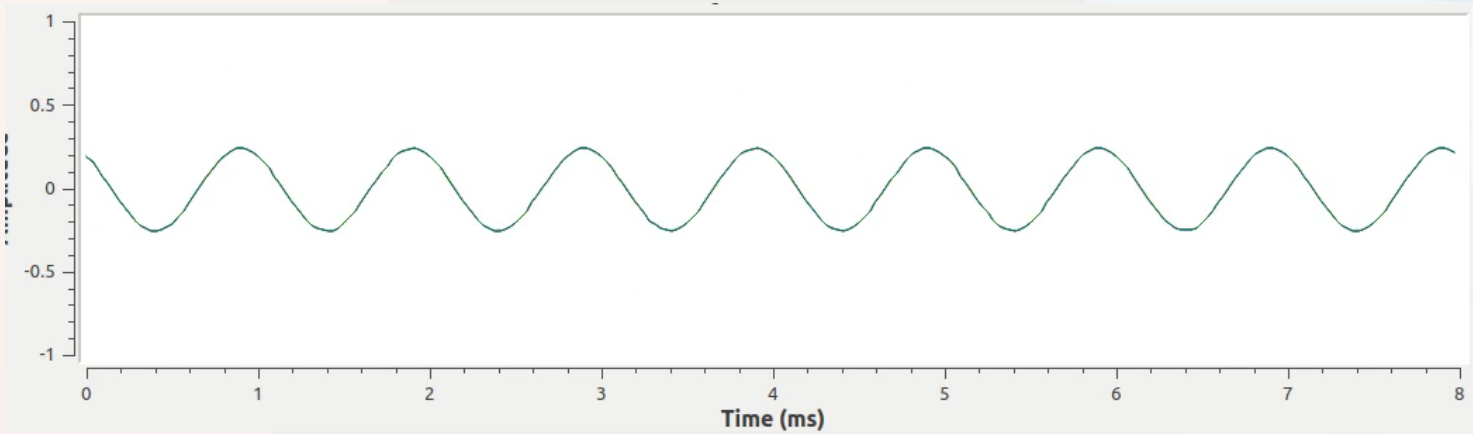
$$s(x_a, y_a, \omega) = re^{j\Phi} = re^{j\omega\frac{2}{c}\sqrt{(x'-x)^2+(y'-y)^2+(z-z_0)^2}}$$

Phase VS Distance



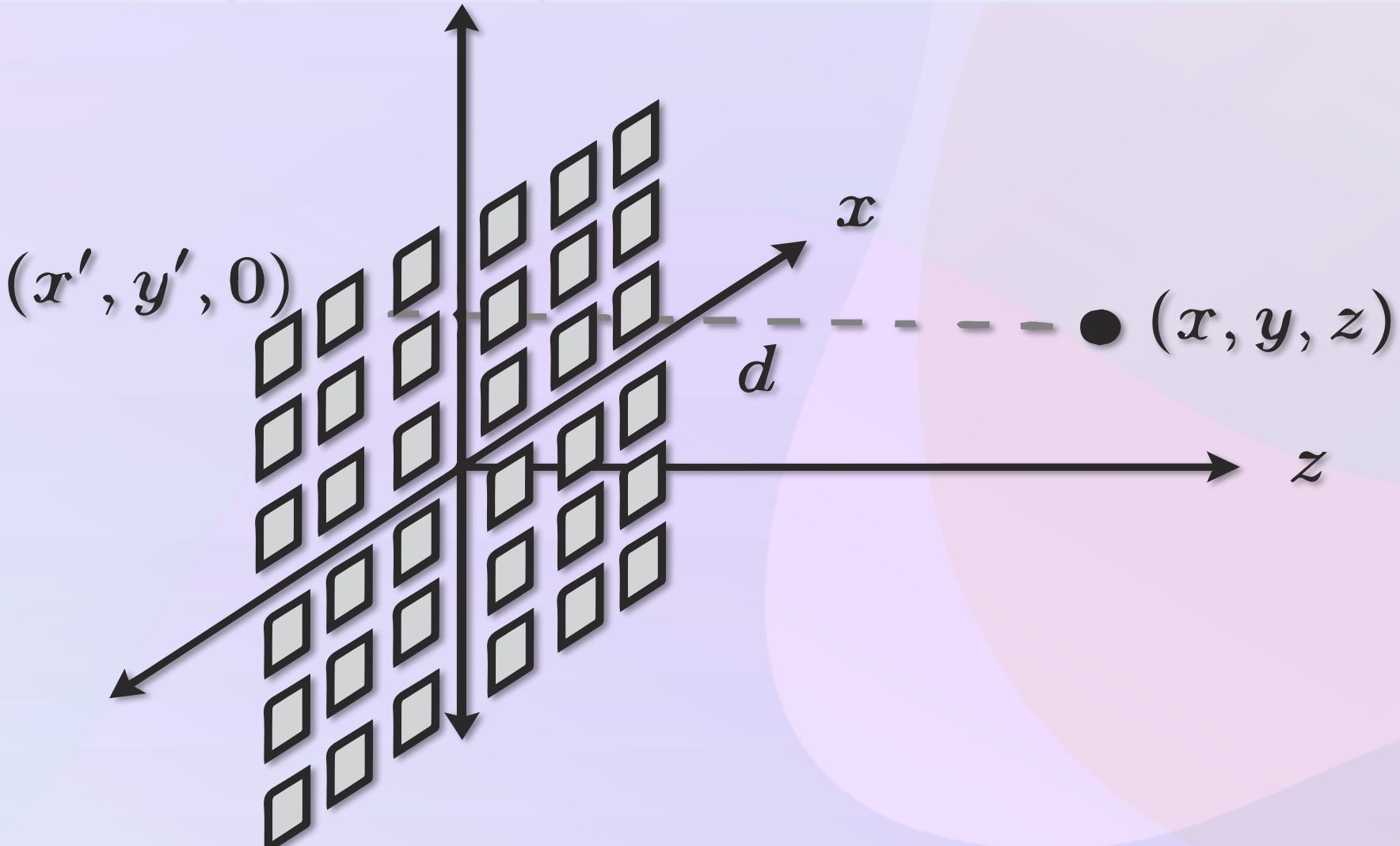






RANGE MIGRATION ALGORITHM

$$s(x', y', \omega') = f(x, y, z)\, e^{-j\omega \frac{2}{c}\sqrt{(x-x_a)^2+(y-y_a)^2+(z-Z_0)^2}}$$



RANGE MIGRATION ALGORITHM

Scan Room

1. Transmit single CW
2. Record reflection
3. Repeat for f frequencies

Repeat for each (X,Y) position

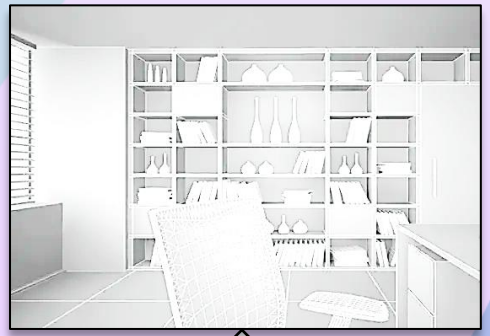
3D array $S(x_a, y_a, \omega)$
[X dim][Y dim][freq dim]

2D FFT
$(x_a, y_a) \rightarrow (k_{xa}, k_{ya})$

Stolt Interpolation
$(k_{xa}, k_{ya}, \omega) \rightarrow (k_x, k_y, k_z)$

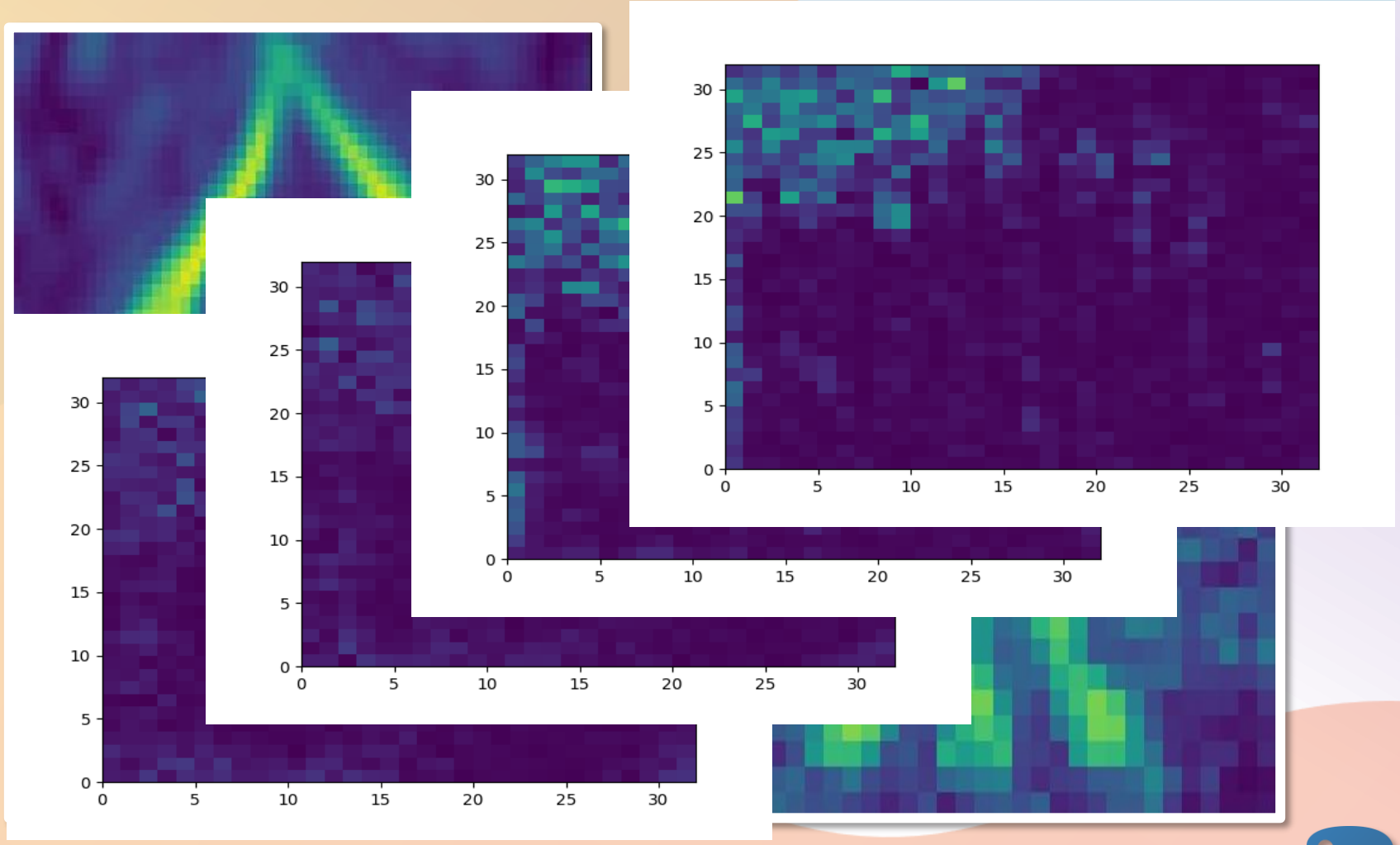
3D IFFT
$(k_x, k_y, k_z) \rightarrow (x, y, z)$

3D array of Scene reflectivity
$f(x, y, z)$



$$f(x,y,z) = IFT_{3D}\left\{Stolt\{FT_{2D}\{s(x_a,y_a,\omega)\}\}e_z^{-jk_z z_0}\right\}$$

Simulation

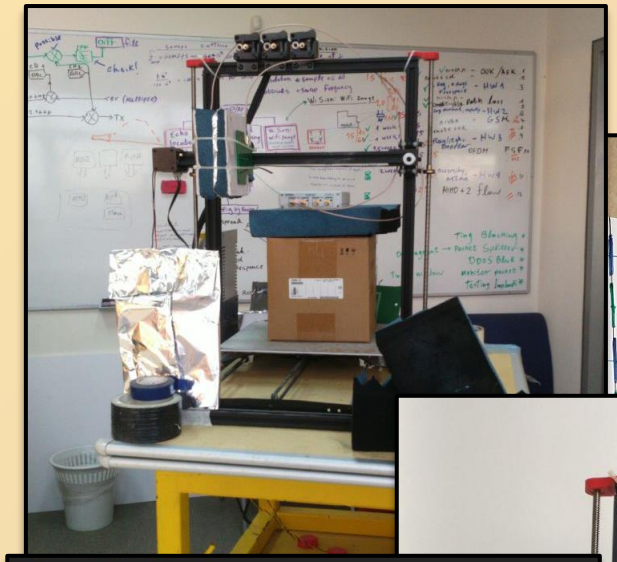


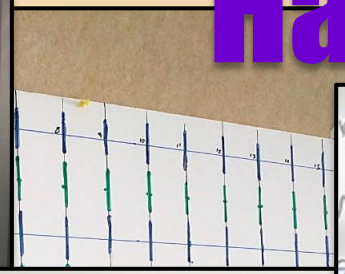
128X128X256

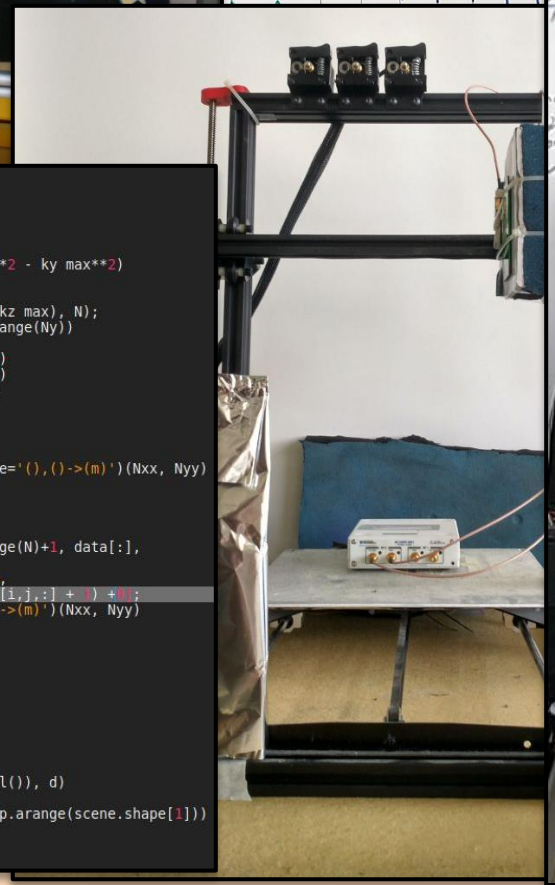
32X32X64

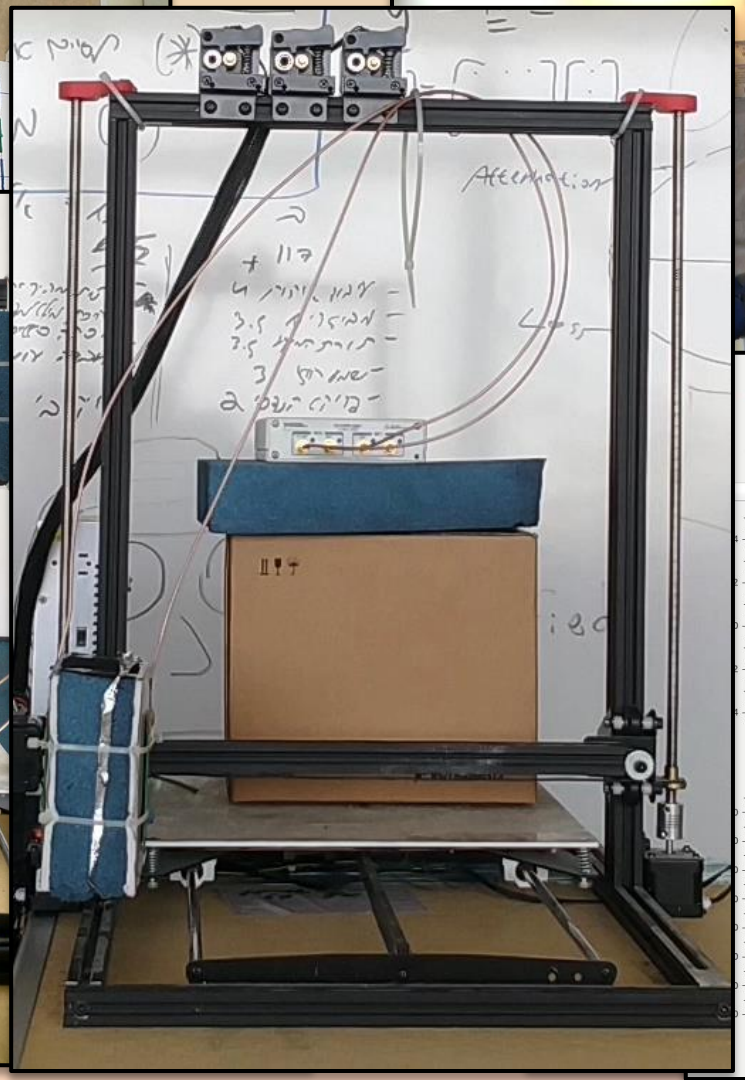
Simulated BGU Logo

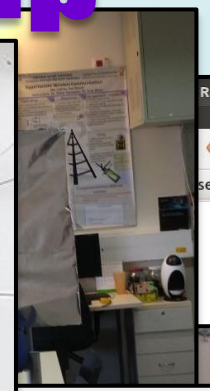
Experimentation Hardware setup

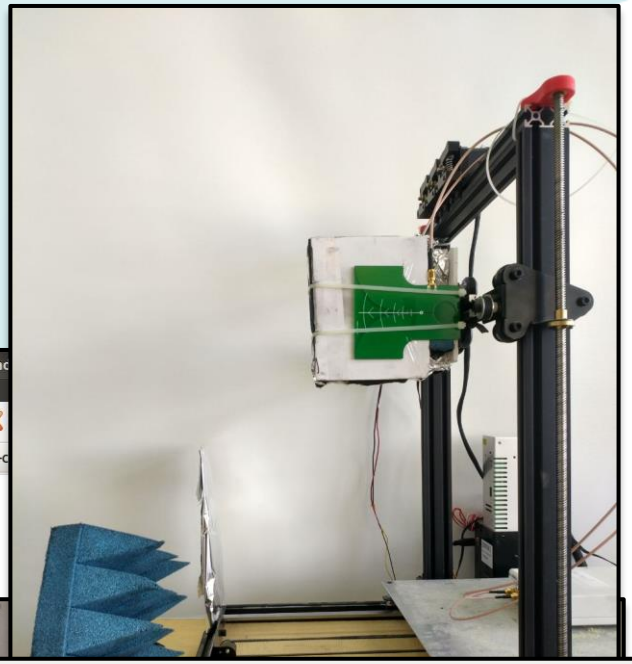








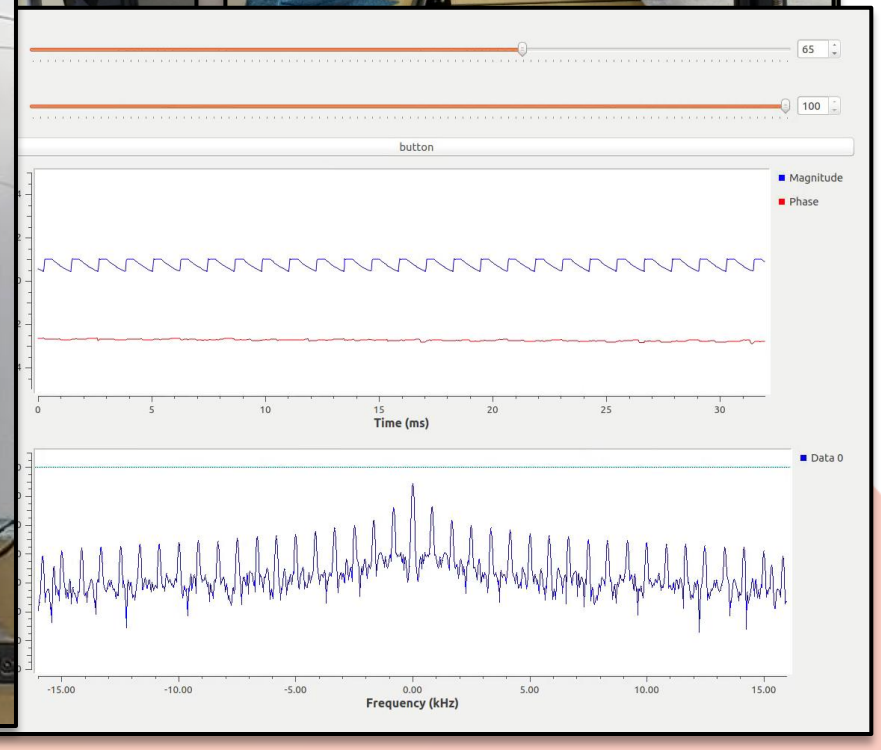




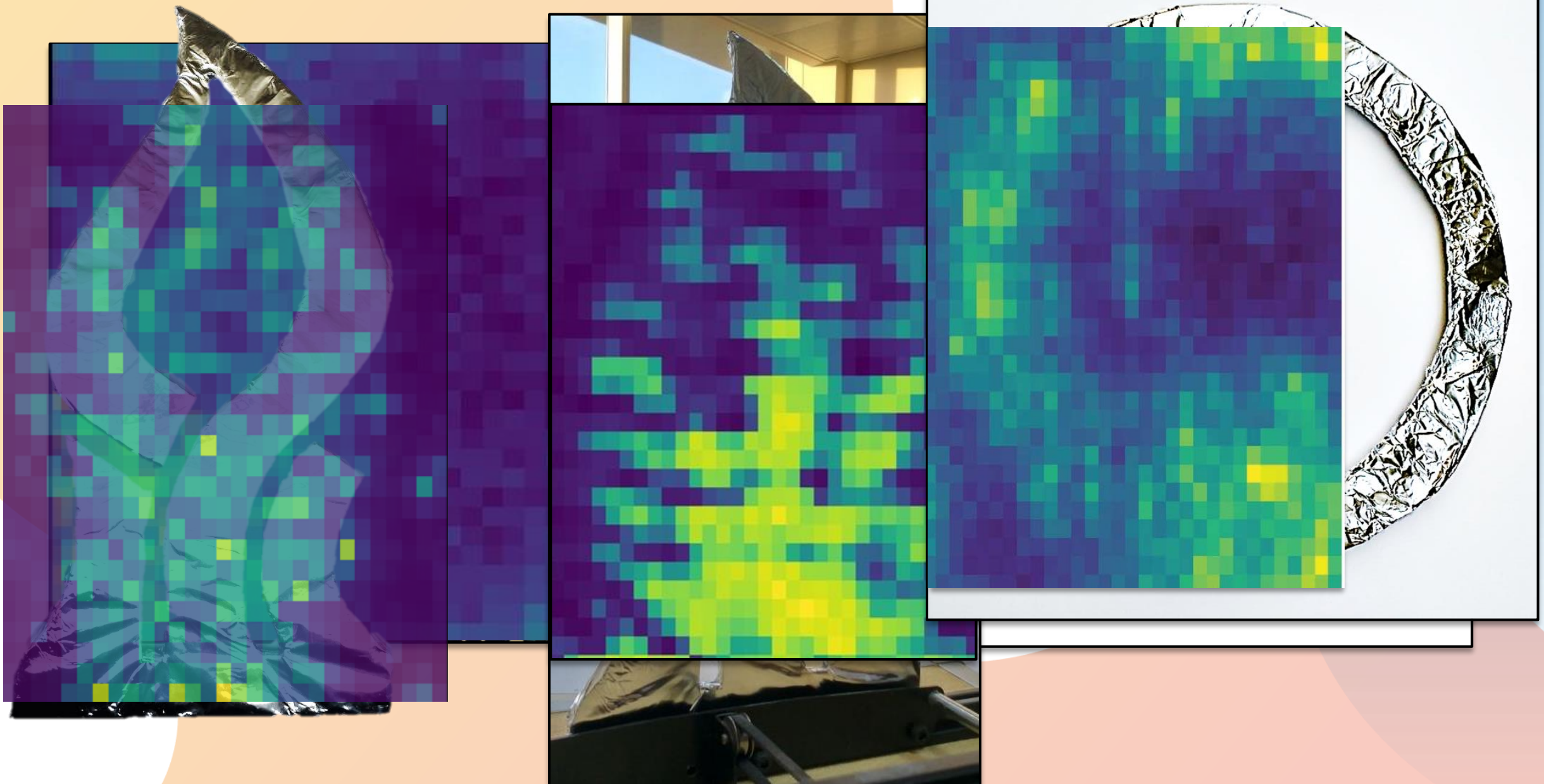
```
f max = f0 + (N-1)*Df;
k min = 2*np.pi*f0/c;
k max = 2*np.pi*f max/c;
kx max = (Nx-1)/Nx * 2*np.pi/Dx / 2;
ky max = (Ny-1)/Ny * 2*np.pi/Dy / 2;
kz min = np.sqrt(0j + 4*k min**2 - kx max**2 - ky max**2)
kz max = np.sqrt(0j + 4*k max**2 - 0 - 0)

kz = np.linspace(np.real(kz min), np.real(kz max), N);
Nxx, Nyy = np.meshgrid(np.arange(Nx),np.arange(Ny))
def E compute row(i,j):
     k = 0.5*np.sqrt(0j + np.power(kx[i],2)
                        + np.power(ky[j],2)
                        + np.power(kz,2));
    w = c* k;
    f = w / (2*np.pi)
    n = ((c* k)/(2*np.pi) - f0)/Df;
    return n
EE  = np.vectorize(E compute row, signature='(),()->(m)')(Nxx, Nyy)
EE = np.transpose(EE, (1,0,2))
E = np.zeros(EE.shape)*1j
def interp1(i,j):
    data = D[i,j,:].reshape((1,1,N))
    return sc.interpolate.interp1d(np.arange(N)+1, data[:],
                        kind='linear',
                        bounds error=False,
                        fill value=(0))(EE[i,j,:] + 1) +0j;
E = np.vectorize(interp1, signature='(),()->(m)')(Nxx, Nyy)
print("E Computed")
# IFFT
E = np.transpose(E, (0,1,2))
R = np.fft.ifftn(E, axes=(2,1,0))
R = np.flip(R, axis=0)
print("R Computed")
return R;

= SAR(mat)
= {'scene 512' : R}
c.io.savemat('{0}.mat'.format(np.random.normal()), d)
cene = np.linalg.norm(R, axis=(2))
, Y = np.meshgrid(np.arange(scene.shape[0]),np.arange(scene.shape[1]))
rint(scene.shape[1])
lt.pcolormesh(X, Y, scene)
lt.show()
```



RMA results



Conclusion

WiFi Data

Radio Frequency
CW Scan

RSSI Triangulation

RMA Image Contraction

Config Node

References

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Questions?