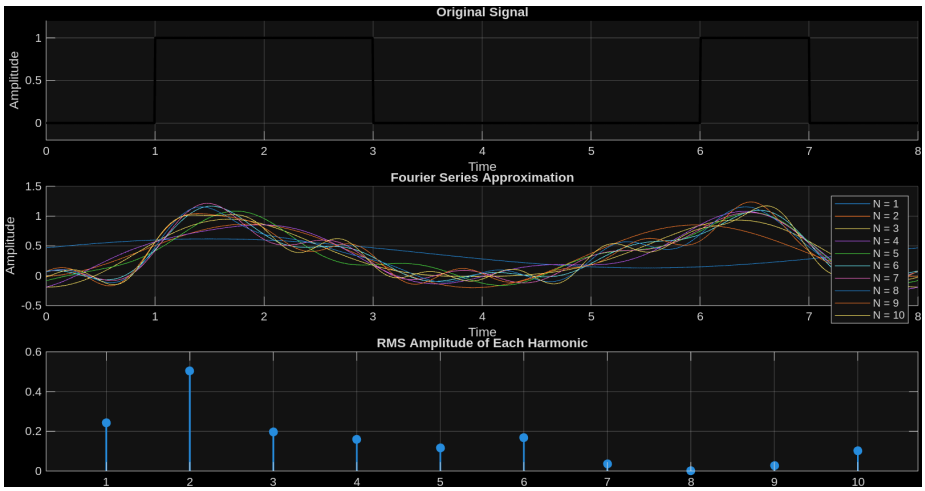
Project 1

q1

code can be found in Appendix 1

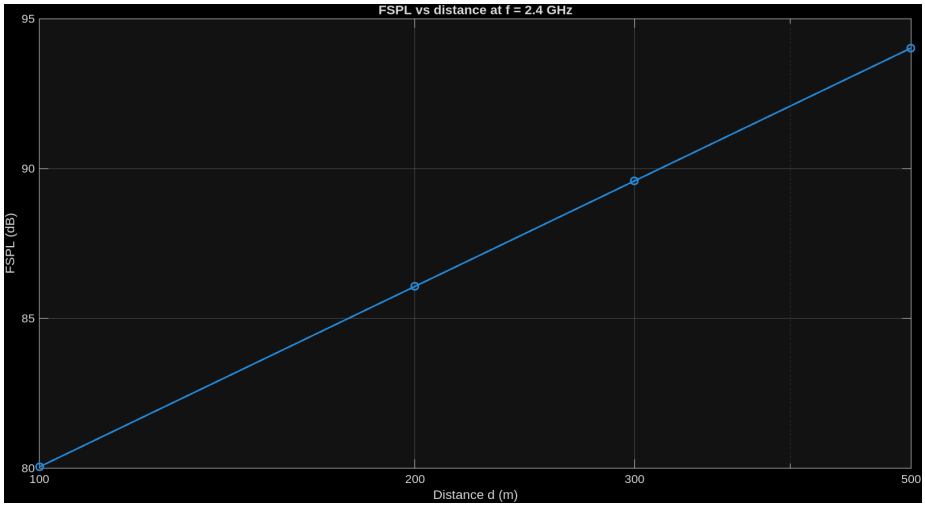


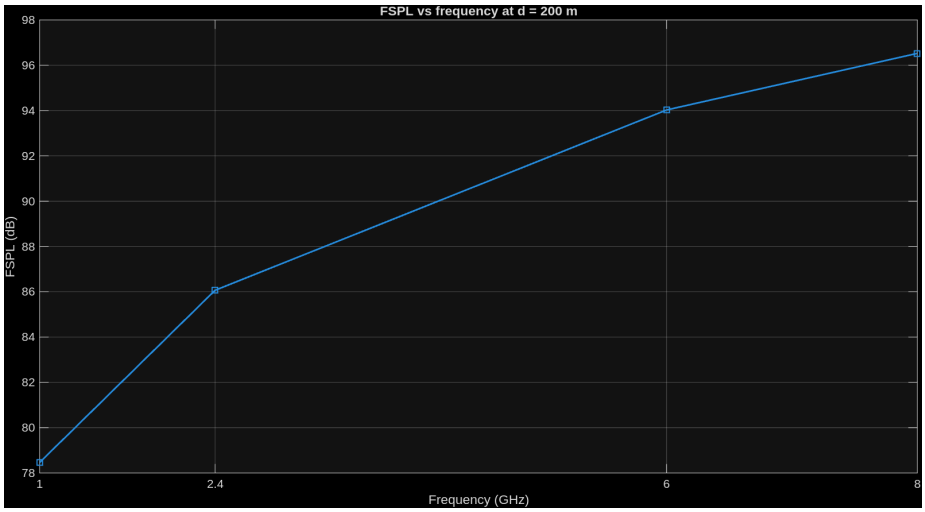
3a. i i belive it may be possible to reconstruct the original signal from 10 samples, but i think for clarity more samples would be better.

q2

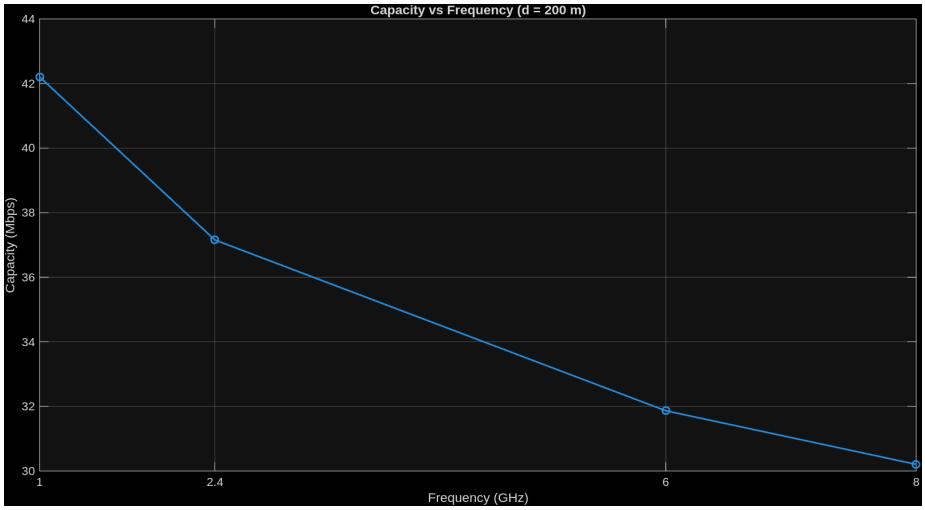
code can be found in Appendix 2

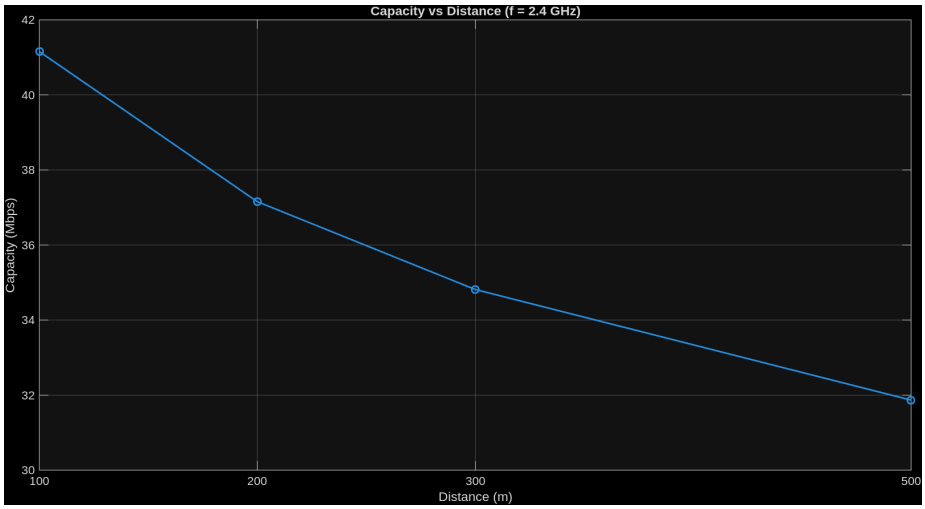
2a.




FSPL vs frequency at d = 200 m
FSPL (dB)
98
96
94
92
90
88
86
84
82
80
78
1
2.4
6
8
Frequency (GHz)

2b.


Capacity vs Frequency (d = 200 m)
Capacity (Mbps)
44
42
40
38
36
34
32
30
1
2.4
6
8
Frequency (GHz)



q3

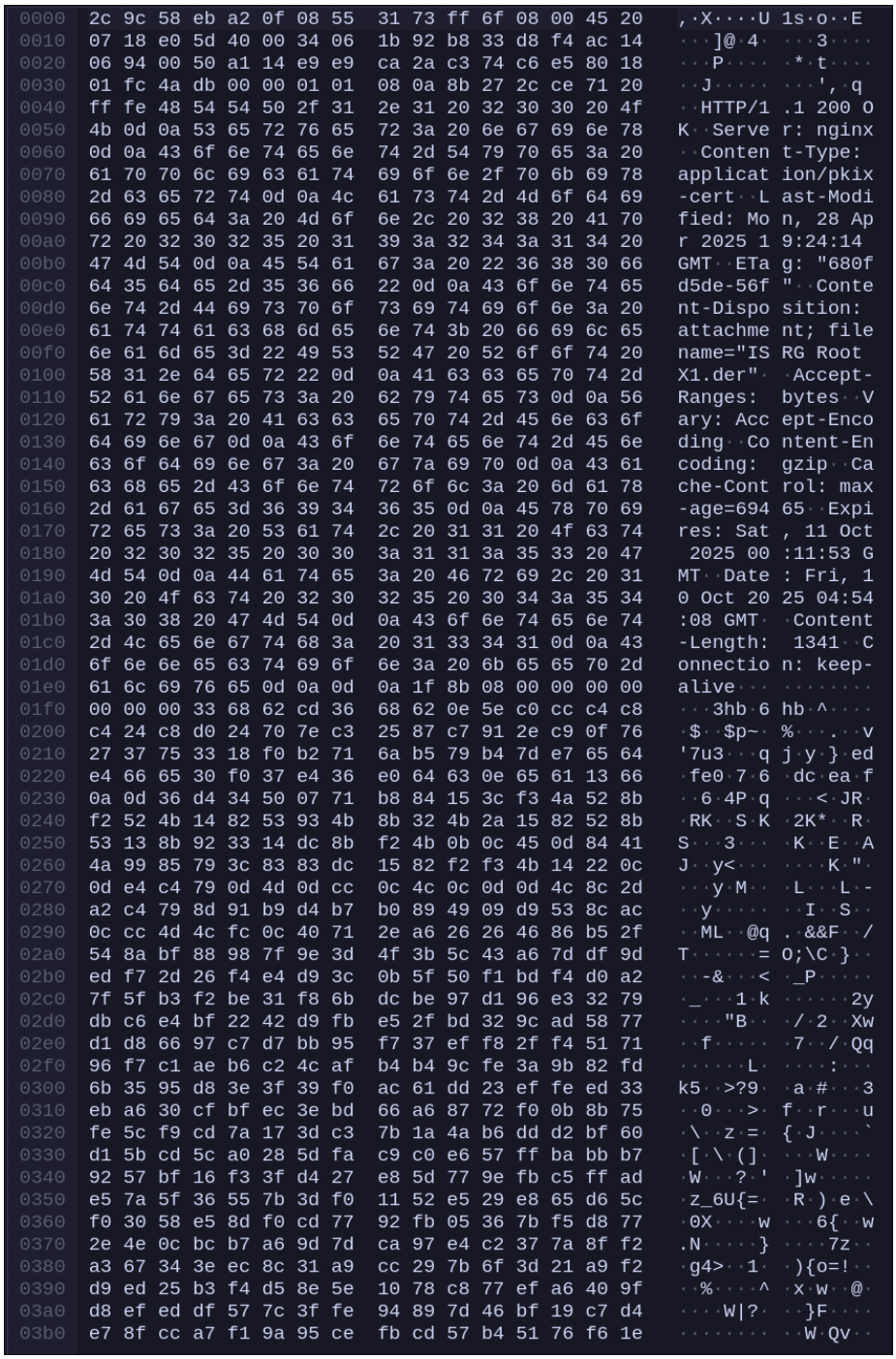
```
0000  08 55 31 73 ff 6f 2c 9c  58 eb a2 0f 08 00 45 00   ·U1s·o,· X·····E·
0010  01 28 b7 cc 40 00 40 06  3e 33 ac 14 06 94 b8 33   ·(··@·@· >3·····3
0020  d8 f4 a1 14 00 50 c3 74  c5 f1 e9 e9 ca 2a 80 18   ·····P·t ·····*··
0030  01 f6 45 bd 00 00 01 01  08 0a 71 20 ff fe 8b 27   ··E····· ··q ···'
0040  2c 96 47 45 54 20 2f 20  48 54 54 50 2f 31 2e 31   ,·GET /  HTTP/1.1
0050  0d 0a 48 6f 73 74 3a 20  78 31 2e 69 2e 6c 65 6e   ··Host:  x1.i.len
0060  63 72 2e 6f 72 67 0d 0a  43 6f 6e 6e 65 63 74 69   cr.org·· Connecti
0070  6f 6e 3a 20 6b 65 65 70  2d 61 6c 69 76 65 0d 0a   on: keep -alive··
0080  55 73 65 72 2d 41 67 65  6e 74 3a 20 4d 6f 7a 69   User-Age nt: Mozi
0090  6c 6c 61 2f 35 2e 30 20  28 58 31 31 3b 20 4c 69   lla/5.0  (X11; Li
00a0  6e 75 78 20 78 38 36 5f  36 34 29 20 41 70 70 6c   nux x86_ 64) Appl
00b0  65 57 65 62 4b 69 74 2f  35 33 37 2e 33 36 20 28   eWebKit/ 537.36 (
00c0  4b 48 54 4d 4c 2c 20 6c  69 6b 65 20 47 65 63 6b   KHTML, l ike Geck
00d0  6f 29 20 43 68 72 6f 6d  65 2f 31 34 30 2e 30 2e   o) Chrom e/140.0.
00e0  30 2e 30 20 53 61 66 61  72 69 2f 35 33 37 2e 33   0.0 Safa ri/537.3
00f0  36 0d 0a 41 63 63 65 70  74 2d 45 6e 63 6f 64 69   6··Accep t-Encodi
0100  6e 67 3a 20 67 7a 69 70  2c 20 64 65 66 6c 61 74   ng: gzip , deflat
0110  65 0d 0a 41 63 63 65 70  74 2d 4c 61 6e 67 75 61   e··Accep t-Langua
0120  67 65 3a 20 65 6e 2d 55  53 2c 65 6e 3b 71 3d 30   ge: en-U S,en;q=0
0130  2e 39 0d 0a 0d 0a                                 .9····
```

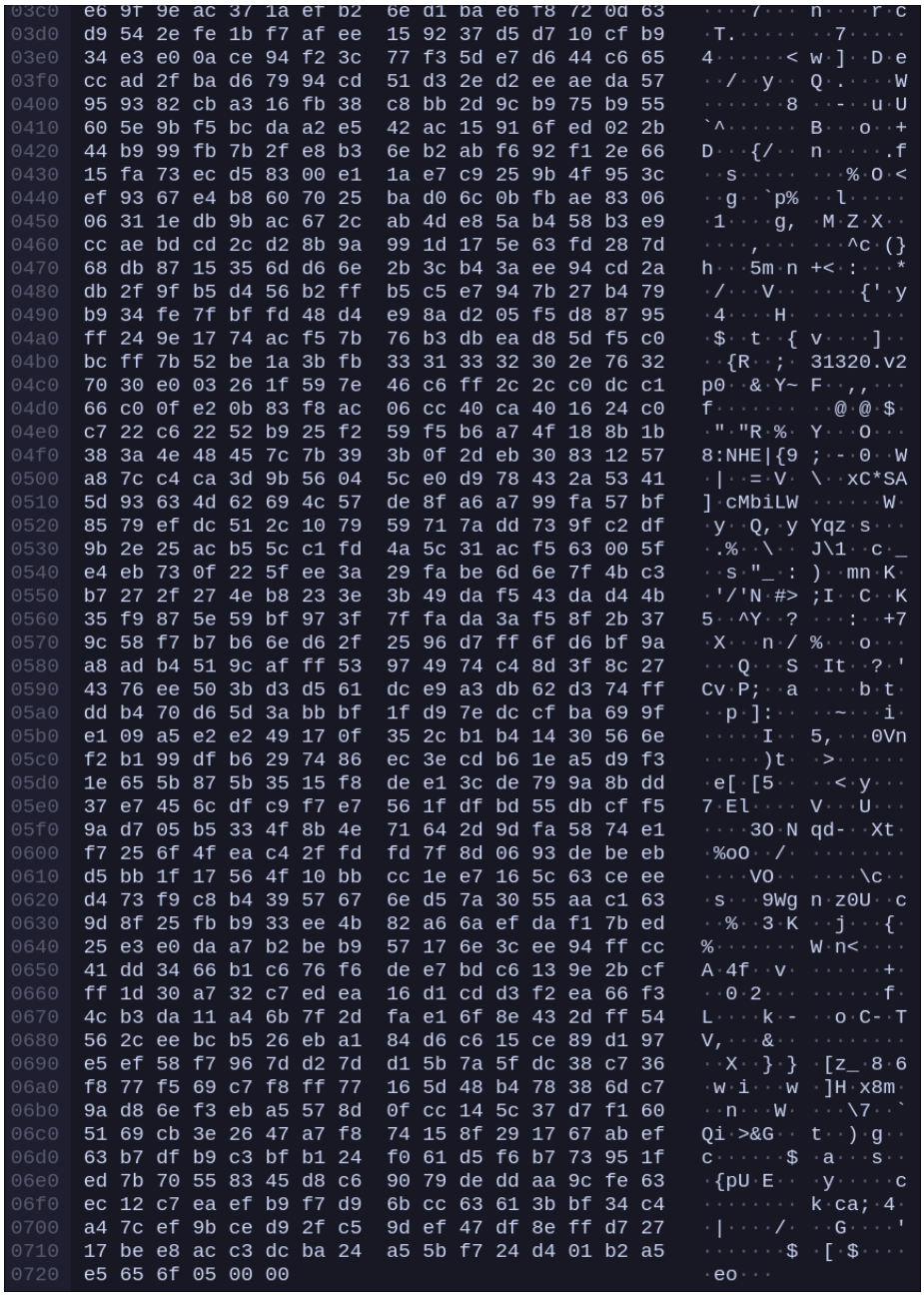
3a. 2c 9c 58 eb a2 0f

3b. 08 55 31 73 ff 6f it is the address of my router

3c. 80 00 IPv4

3d. byte 0042 which is 66 in decimal making it the 67th byte


0000 2c 9c 58 eb a2 0f 08 55 31 73 ff 6f 08 00 45 20 ,·X····U 1s·o··E
0010 07 18 e0 5d 40 00 34 06 1b 92 b8 33 d8 f4 ac 14 ···]@·4· ···3····
0020 06 94 00 50 a1 14 e9 e9 ca 2a c3 74 c6 e5 80 18 ···P···· ·*·t····
0030 01 fc 4a db 00 00 01 01 08 0a 8b 27 2c ce 71 20 ··J····· ···',·q
0040 ff fe 48 54 54 50 2f 31 2e 31 20 32 30 30 20 4f ··HTTP/1 .1 200 O
0050 4b 0d 0a 53 65 72 76 65 72 3a 20 6e 67 69 6e 78 K··Serve r: nginx
0060 0d 0a 43 6f 6e 74 65 6e 74 2d 54 79 70 65 3a 20 ··Conten t-Type:
0070 61 70 70 6c 69 63 61 74 69 6f 6e 2f 70 6b 69 78 applicat ion/pkix
0080 2d 63 65 72 74 0d 0a 4c 61 73 74 2d 4d 6f 64 69 -cert··L ast-Modi
0090 66 69 65 64 3a 20 4d 6f 6e 2c 20 32 38 20 41 70 fied: Mo n, 28 Ap
00a0 72 20 32 30 32 35 20 31 39 3a 32 34 3a 31 34 20 r 2025 1 9:24:14
00b0 47 4d 54 0d 0a 45 54 61 67 3a 20 22 36 38 30 66 GMT··ETa g: "680f
00c0 64 35 64 65 2d 35 36 66 22 0d 0a 43 6f 6e 74 65 d5de-56f "··Conte
00d0 6e 74 2d 44 69 73 70 6f 73 69 74 69 6f 6e 3a 20 nt-Dispo sition:
00e0 61 74 74 61 63 68 6d 65 6e 74 3b 20 66 69 6c 65 attachme nt; file
00f0 6e 61 6d 65 3d 22 49 53 52 47 20 52 6f 6f 74 20 name="IS RG Root
0100 58 31 2e 64 65 72 22 0d 0a 41 63 63 65 70 74 2d X1.der"· ·Accept-
0110 52 61 6e 67 65 73 3a 20 62 79 74 65 73 0d 0a 56 Ranges: bytes··V
0120 61 72 79 3a 20 41 63 63 65 70 74 2d 45 6e 63 6f ary: Acc ept-Enco
0130 64 69 6e 67 0d 0a 43 6f 6e 74 65 6e 74 2d 45 6e ding··Co ntent-En
0140 63 6f 64 69 6e 67 3a 20 67 7a 69 70 0d 0a 43 61 coding: gzip··Ca
0150 63 68 65 2d 43 6f 6e 74 72 6f 6c 3a 20 6d 61 78 che-Cont rol: max
0160 2d 61 67 65 3d 36 39 34 36 35 0d 0a 45 78 70 69 -age=694 65··Expi
0170 72 65 73 3a 20 53 61 74 2c 20 31 31 20 4f 63 74 res: Sat , 11 Oct
0180 20 32 30 32 35 20 30 30 3a 31 31 3a 35 33 20 47 2025 00 :11:53 G
0190 4d 54 0d 0a 44 61 74 65 3a 20 46 72 69 2c 20 31 MT··Date : Fri, 1
01a0 30 20 4f 63 74 20 32 30 32 35 20 30 34 3a 35 34 0 Oct 20 25 04:54
01b0 3a 30 38 20 47 4d 54 0d 0a 43 6f 6e 74 65 6e 74 :08 GMT· ·Content
01c0 2d 4c 65 6e 67 74 68 3a 20 31 33 34 31 0d 0a 43 -Length: 1341··C
01d0 6f 6e 6e 65 63 74 69 6f 6e 3a 20 6b 65 65 70 2d onnectio n: keep-
01e0 61 6c 69 76 65 0d 0a 0d 0a 1f 8b 08 00 00 00 00 alive··· ·····
01f0 00 00 00 33 68 62 cd 36 68 62 0e 5e c0 cc c4 c8 ···3hb·6 hb·^····
0200 c4 24 c8 d0 24 70 7e c3 25 87 c7 91 2e c9 0f 76 ·$··$p~· %····.··v
0210 27 37 75 33 18 f0 b2 71 6a b5 79 b4 7d e7 65 64 '7u3···q j·y·}·ed
0220 e4 66 65 30 f0 37 e4 36 e0 64 63 0e 65 61 13 66 ·fe0·7·6 ·dc·ea·f
0230 0a 0d 36 d4 34 50 07 71 b8 84 15 3c f3 4a 52 8b ··6·4P·q ···<·JR·
0240 f2 52 4b 14 82 53 93 4b 8b 32 4b 2a 15 82 52 8b ·RK··S·K ·2K*··R·
0250 53 13 8b 92 33 14 dc 8b f2 4b 0b 0c 45 0d 84 41 S···3··· ·K··E··A
0260 4a 99 85 79 3c 83 83 dc 15 82 f2 f3 4b 14 22 0c J··y<··· ····K·"·
0270 0d e4 c4 79 0d 4d 0d cc 0c 4c 0c 0d 0d 4c 8c 2d ···y·M·· ·L···L··-
0280 a2 c4 79 8d 91 b9 d4 b7 b0 89 49 09 d9 53 8c ac ··y····· ··I··S··
0290 0c cc 4d 4c fc 0c 40 71 2e a6 26 26 46 86 b5 2f ··ML··@q ·.&&F··/
02a0 54 8a bf 88 98 7f 9e 3d 4f 3b 5c 43 a6 7d df 9d T·····= O;\C·}··
02b0 ed f7 2d 26 f4 e4 d9 3c 0b 5f 50 f1 bd f4 d0 a2 ··-&···< ·_P·····
02c0 7f 5f b3 f2 be 31 f8 6b dc be 97 d1 96 e3 32 79 ·_···1·k ·····2y
02d0 db c6 e4 bf 22 42 d9 fb e5 2f bd 32 9c ad 58 77 ····"B·· ·/·2··Xw
02e0 d1 d8 66 97 c7 d7 bb 95 f7 37 ef f8 2f f4 51 71 ··f····· ·7··/·Qq
02f0 96 f7 c1 ae b6 c2 4c af b4 b4 9c fe 3a 9b 82 fd ·····L· ····:···
0300 6b 35 95 d8 3e 3f 39 f0 ac 61 dd 23 ef fe ed 33 k5··>?9· ·a·#···3
0310 eb a6 30 cf bf ec 3e bd 66 a6 87 72 f0 0b 8b 75 ··0···>· f··r···u
0320 fe 5c f9 cd 7a 17 3d c3 7b 1a 4a b6 dd d2 bf 60 ·\··z·=· {·J····`
0330 d1 5b cd 5c a0 28 5d fa c9 c0 e6 57 ff ba bb b7 ·[·\·(]· ···W····
0340 92 57 bf 16 f3 3f d4 27 e8 5d 77 9e fb c5 ff ad ·W···?·' ·]w·····
0350 e5 7a 5f 36 55 7b 3d f0 11 52 e5 29 e8 65 d6 5c ·z_6U{=· ·R·)·e·\
0360 f0 30 58 e5 8d f0 cd 77 92 fb 05 36 7b f5 d8 77 ·0X····w ···6{··w
0370 2e 4e 0c bc b7 a6 9d 7d ca 97 e4 c2 37 7a 8f f2 .N·····} ····7z··
0380 a3 67 34 3e ec 8c 31 a9 cc 29 7b 6f 3d 21 a9 f2 ·g4>··1· ·){o=!··
0390 d9 ed 25 b3 f4 d5 8e 5e 10 78 c8 77 ef a6 40 9f ··%····^ ·x·w··@·
03a0 d8 ef ed df 57 7c 3f fe 94 89 7d 46 bf 19 c7 d4 ····W|?· ··}F····
03b0 e7 8f cc a7 f1 9a 95 ce fb cd 57 b4 51 76 f6 1e ········ ··W·Qv··



3e. 08 55 31 73 ff 6f this is the same address as the destination of the last packet, it is my router

3f. 2c 9c 58 eb a2 0f yes it is

3g 08 00 IPV4

3h. it is also byte 0042, therefor it is also the 67th byte

q4

```
carter@carter:~$ arp
Address                  HWtype  HWaddress           Flags Mask            Iface
172.20.2.148                     (incomplete)                              wlp1s0
172.20.10.199                    (incomplete)                              wlp1s0
_gateway                 ether   08:55:31:73:ff:6f   C                     wlp1s0
172.20.0.141                     (incomplete)                              wlp1s0
172.20.12.87                     (incomplete)                              wlp1s0
172.20.3.228                     (incomplete)                              wlp1s0
172.20.7.252                     (incomplete)                              wlp1s0
172.20.8.187                     (incomplete)                              wlp1s0
172.20.13.214                    (incomplete)                              wlp1s0
carter@carter:~$
```

4a. the address is the ip adress, HWtype is the type of connection, HW address is the mac address, Flags indicate if the mac adress is complete or not, and whether it was manually set or not, iface is the interface that each address is connecting through

```
ff ff ff ff ff ff 2c 9c  58 eb a2 0f 08 06 00 01
08 00 06 04 00 01 2c 9c  58 eb a2 0f ac 14 06 94
00 00 00 00 00 00 ac 14  0d d6
```

```
carter@carter:~$ arp
Address                  HWtype  HWaddress           Flags Mask            Iface
172.20.2.148                     (incomplete)                              wlp1s0
172.20.10.199                    (incomplete)                              wlp1s0
_gateway                 ether   08:55:31:73:ff:6f   C                     wlp1s0
172.20.0.141                     (incomplete)                              wlp1s0
172.20.12.87                     (incomplete)                              wlp1s0
172.20.3.228                     (incomplete)                              wlp1s0
172.20.7.252                     (incomplete)                              wlp1s0
172.20.8.187                     (incomplete)                              wlp1s0
172.20.13.214                    (incomplete)                              wlp1s0
carter@carter:~$
```

4b. Source: 2c 9c 58 eb a2 0f Destination: ff ff ff ff ff ff

4c. 0806 ARP

4d. i. 14 bytes ii. 00 01 request iii. yes iv. at the very end of the packet

4e. i. 14 again ii. 00 02 reply iii. right before the target ip address

4f. (i didnt get a response from the device i pinged, but i did get a response from a different device so i will use that instead)

source: (2c:9c:58:eb:a2:0f) Destination: (08:55:31:73:ff:6f)

APPENDIX

1

```
clear;
clc;
close all;

T=8;
f = 1/T;
t = linspace(0, T, 1000);

bits = [0 1 1 0 0 0 1 0];
signal = zeros(size(t));

for k = 1:8
    signal(t >= (k-1) & t<k) = bits(k);
end

figure;
subplot(3,1,1);
hold on;
plot(t, signal, 'k', 'LineWidth', 2);
ylim([-0.2 1.2]);
title('Original Signal');
xlabel('Time');
ylabel('Amplitude');
grid on;


c = 3/4;
N_Values = 1:10;
colors = lines(length(N_Values));


subplot(3,1,2);
hold on;

for N = N_Values
    g = 0.5*c;
    for n = 1:N
        an = (1/(pi*n))*(cos((pi*n)/4)-cos((3*pi*n)/4)+cos((6*pi*n)/4)-cos((7*pi*n)/4));
        bn = (1/(pi*n))*(sin((3*pi*n)/4)-sin((pi*n)/4)+sin((7*pi*n)/4)-sin((6*pi*n)/4));

        g = g + an * sin(2*pi*N*f*t) + bn * cos(2*pi*n*f*t);
```

```
    end

    plot(t, g, 'Color', colors(N,:), 'DisplayName', sprintf('N = %d', N));
end

title('Fourier Series Approximation');
xlabel('Time');
ylabel('Amplitude');
legend show;
grid on;

a_vals = zeros(1,10);
b_vals = zeros(1,10);
rms_vals = zeros(1,10);

for n = 1:10
    a_vals(n) = (1/(pi*n))*(cos((pi*n)/4)-cos((3*pi*n)/4)+cos((6*pi*n)/4)-cos((7*pi*n)/4));
    b_vals(n) = (1/(pi*n))*(sin((3*pi*n)/4)-sin((pi*n)/4)+sin((7*pi*n)/4)-sin((6*pi*n)/4));
    rms_vals(n) = sqrt(a_vals(n)^2 + b_vals(n)^2);
end

subplot(3,1,3);
stem(1:10, rms_vals, 'filled', 'LineWidth', 1.5);
title('RMS Amplitude of Each Harmonic');
grid on;
```

2

```
clear; close all; clc;

c = 3e8;
Pt_dbm = 30;
Gt = 3;
Gr = 1;
L_tx = 1;
L_rx = 2;
N0_dbmHz = -174;
B = 2e6;

% 2a
f_24 = 2.4e9;
d_list = [100, 200, 300, 500];

fspl = @(d,f) 20*log10(4*pi.*d.*f./c);
```

```
FSPL_d = fspl(d_list, f_24);

figure;
semilogx(d_list, FSPL_d, '-o','LineWidth',1.4);
grid on;
xlabel('Distance d (m)'); ylabel('FSPL (dB)');
title('FSPL vs distance at f = 2.4 GHz');
xticks(d_list);

d_fixed = 200;
f_list = [1e9, 2.4e9, 6e9, 8e9];
FSPL_f = fspl(d_fixed, f_list);

figure;
plot(f_list/1e9, FSPL_f, '-s','LineWidth',1.4);
grid on;
xlabel('Frequency (GHz)'); ylabel('FSPL (dB)');
title('FSPL vs frequency at d = 200 m');
xticks(f_list/1e9);

% 2b
recv_power_dbm = @(d,f) Pt_dbm + Gt - L_tx - fspl(d,f) + Gr - L_rx;

N_dbm = N0_dbmHz + 10*log10(B);

% i)
Pr_i = arrayfun(@(f) recv_power_dbm(d_fixed,f), f_list);
SNR_db_i = Pr_i - N_dbm;
SNR_lin_i = 10.^(SNR_db_i/10);
Capacity_i = B .* log2(1 + SNR_lin_i);

% ii)
Pr_ii = arrayfun(@(d) recv_power_dbm(d,f_24), d_list);
SNR_db_ii = Pr_ii - N_dbm;
SNR_lin_ii = 10.^(SNR_db_ii/10);
Capacity_ii = B .* log2(1 + SNR_lin_ii);

fprintf('\nCase (i)\n');
for i=1:length(f_list)
    fprintf(' f=%.1f GHz: Pr = %.3f dBm, SNR = %.3f dB, Capacity = %.3f Mbps\n', ...
        f_list(i)/1e9, Pr_i(i), SNR_db_i(i), Capacity_i(i)/1e6);
end

fprintf('\nCase (ii)\n');
for i=1:length(d_list)
    fprintf(' d=%d m: Pr = %.3f dBm, SNR = %.3f dB, Capacity = %.3f Mbps\n', ...
```

```
        d_list(i), Pr_ii(i), SNR_db_ii(i), Capacity_ii(i)/1e6);
end

figure;
plot(f_list/1e9, Capacity_i/1e6, '-o','LineWidth',1.4);
grid on;
xlabel('Frequency (GHz)'); ylabel('Capacity (Mbps)');
title('Capacity vs Frequency (d = 200 m)');
xticks(f_list/1e9);

figure;
plot(d_list, Capacity_ii/1e6, '-o','LineWidth',1.4);
grid on;
xlabel('Distance (m)'); ylabel('Capacity (Mbps)');
title('Capacity vs Distance (f = 2.4 GHz)');
xticks(d_list);
```