Threat From the Satellite

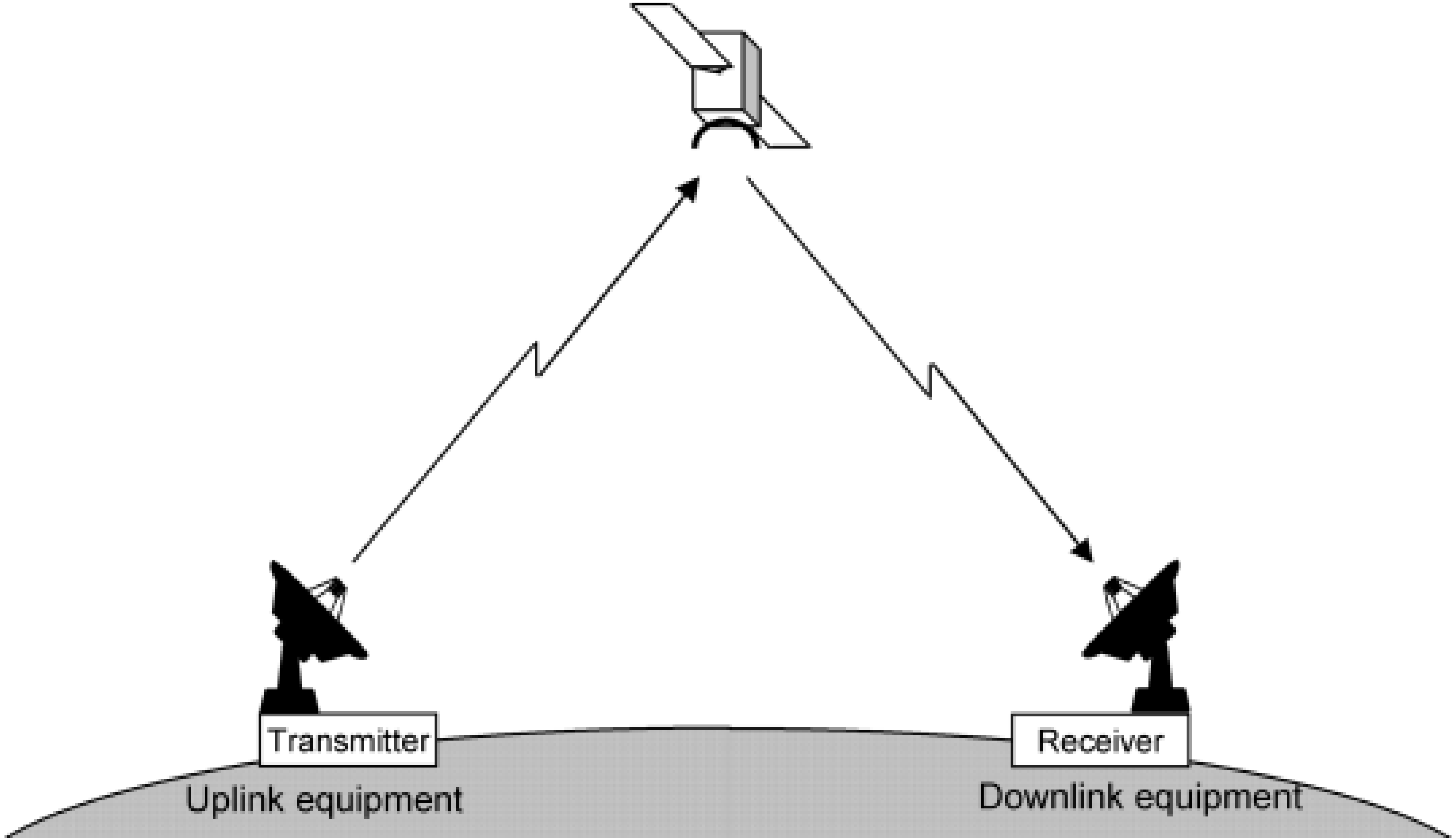
Jingli Hao

WHO ARE WE?

360 TECHNOLOGY
Security Research Institute
Unicorn Team

SATELLITE COMMUNICATION

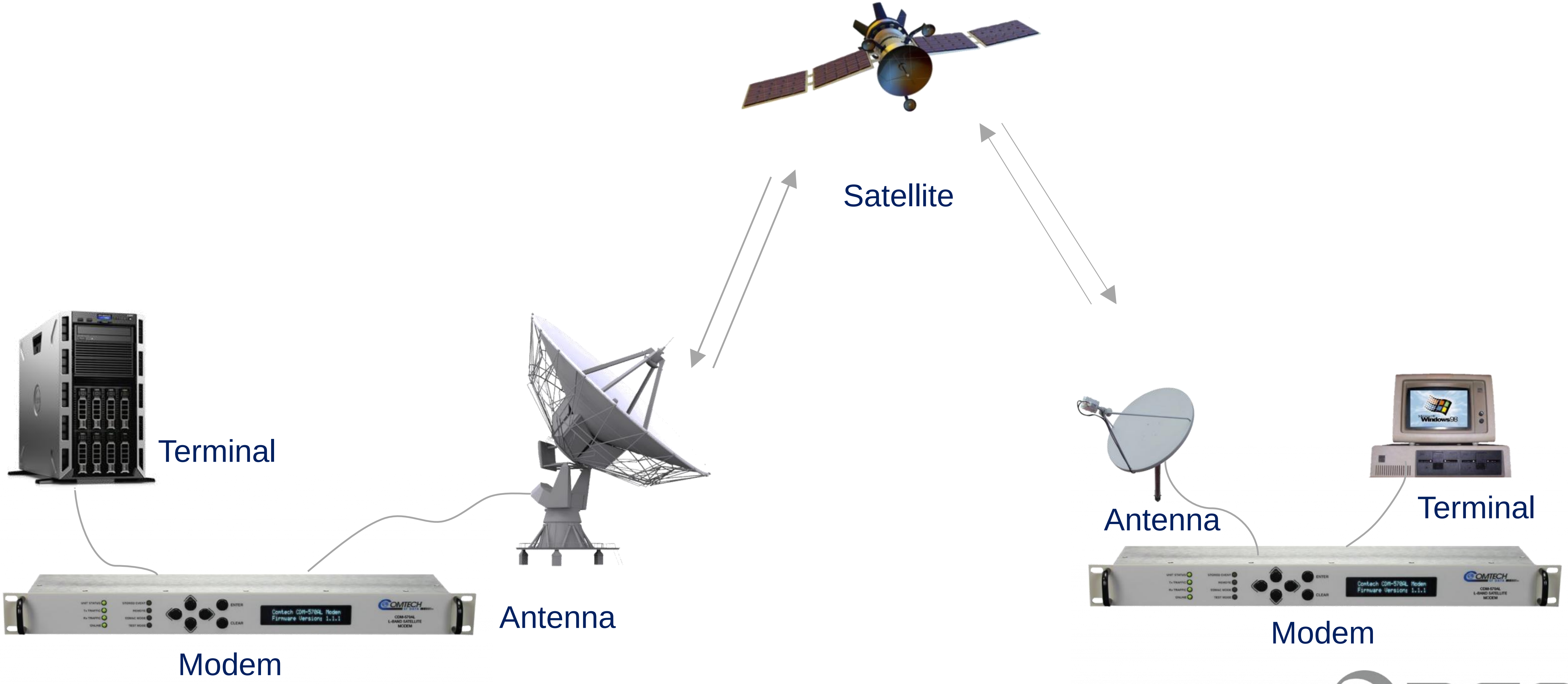
Satellite Communication



Applications

Bank
Telephone
Radio
Internet
Television
Military

COMMUNICATION COMPONENT



Satellite

Terminal

Antenna

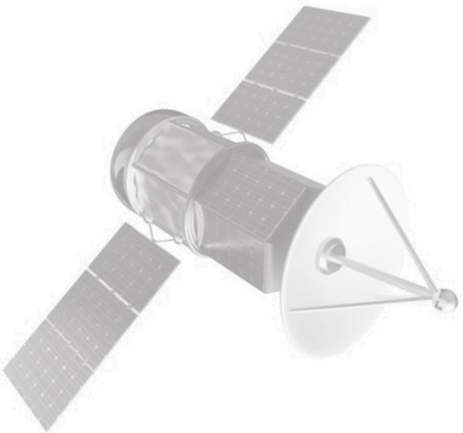
Modem

Antenna

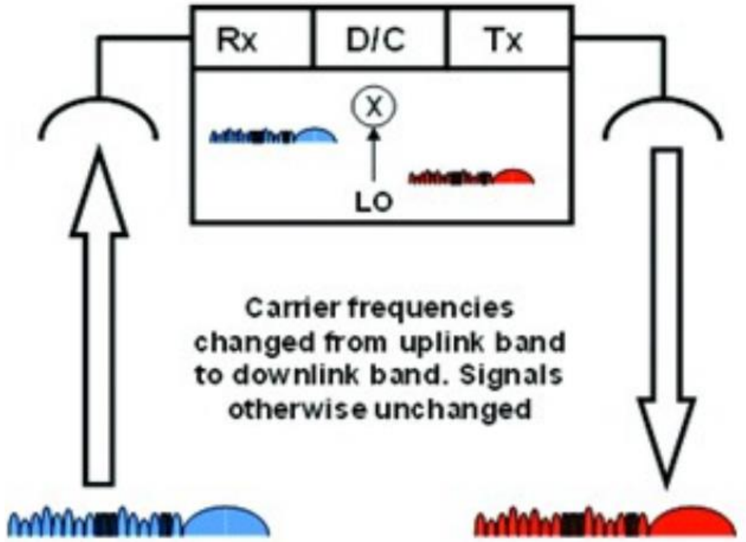
Terminal

Modem

TRANSPONDERS



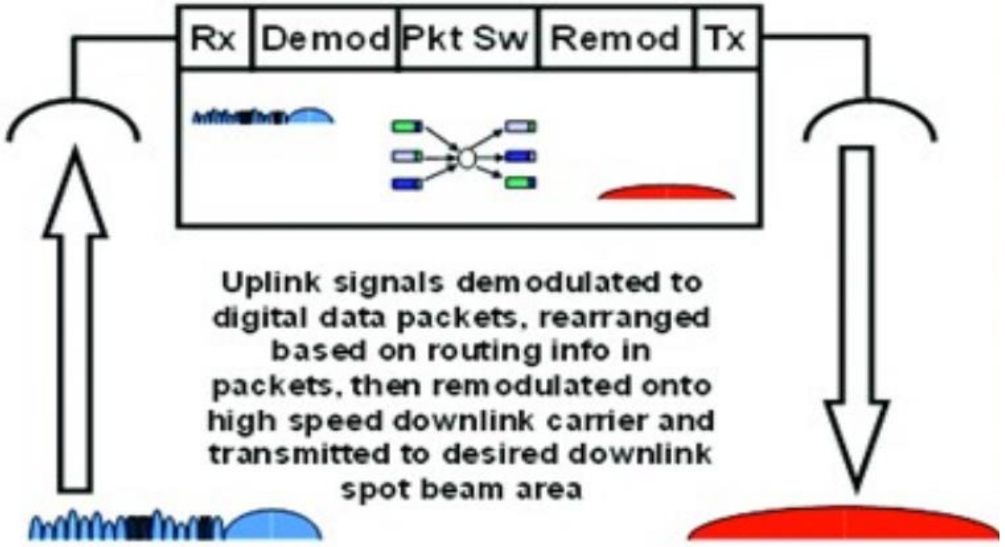
‘Bent Pipe’ Transponder Payload



Carrier frequencies changed from uplink band to downlink band. Signals otherwise unchanged

“Bent Pipe” Transponder Payload

Regenerative Payload



Uplink signals demodulated to digital data packets, rearranged based on routing info in packets, then remodulated onto high speed downlink carrier and transmitted to desired downlink spot beam area

Regenerative Payload

COMMUNICATION SATELLITE

Satellite	Operator	Transponders
spaceway3	HNS	Regenerative Payload
wildblue	Wild-blue	Bent Pipe
Anik-F2/F3	Telesat	Bent Pipe
Viasat-1	Viasat	Bent Pipe
Inmarsat-5	Inmarsat	Bent Pipe
Hotbird-6	Eutelsat	Bent Pipe
Hylas	Avanti	Bent Pipe
Ka-sat	Viasat	Bent Pipe
03b	03b Networks	Bent Pipe
WINDS	JAXA	Regenerative Payload
iPSTAR-5	Thaicom	Bent Pipe
Yahsat1A/1B	Yahsat	Bent Pipe

BE CAREFUL! IF THERE IS A SPY!

Fake Signal

Tampering with data through High-power transmitter

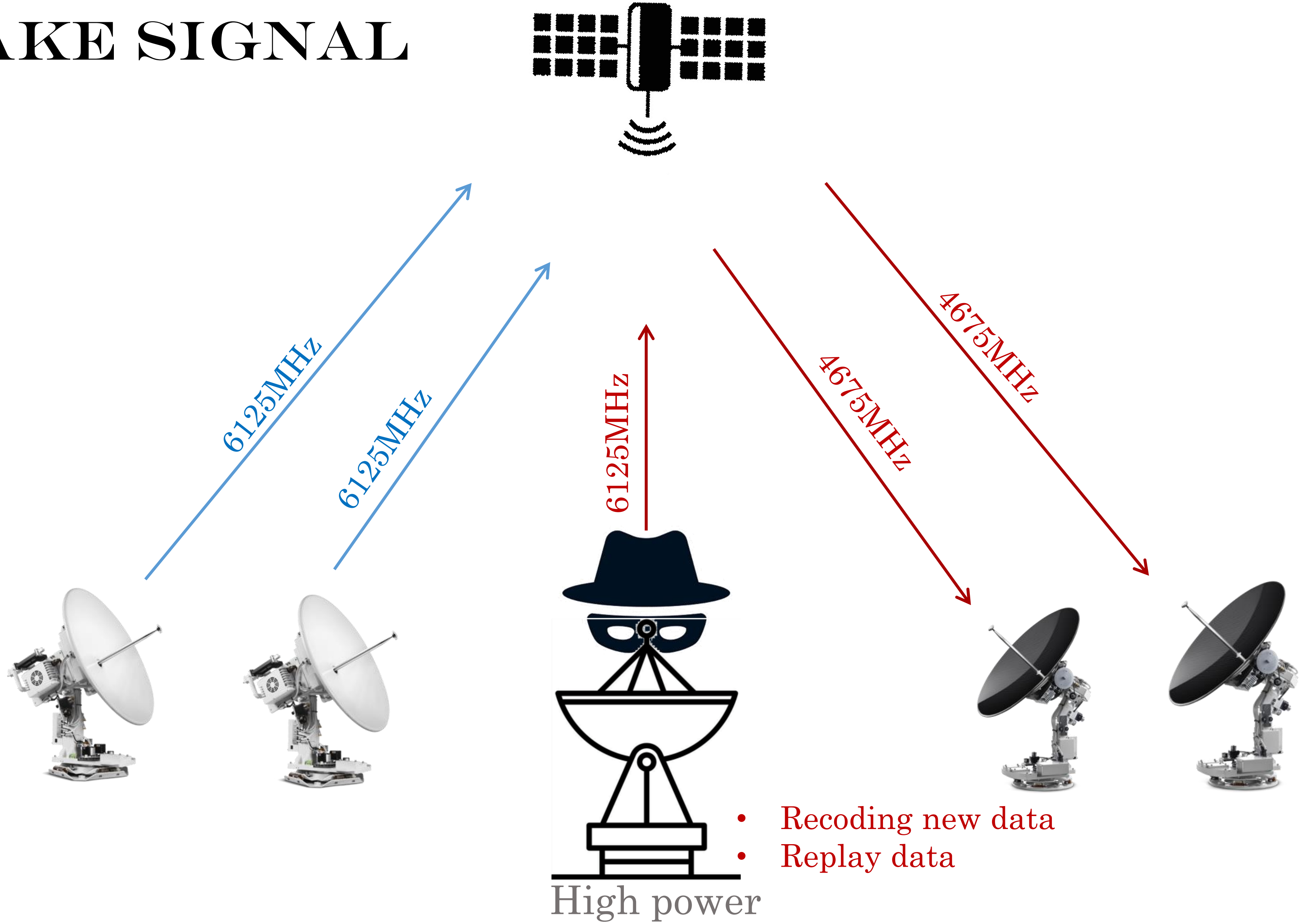
Stealing Communication Links

Calculate the free link and use it.

Jamming

Calculate the uplink frequency and send high power jamming signal.

FAKE SIGNAL



- Recoding new data
- Replay data

STEALING COMMUNICATION LINKS

C-band frequency

Uplink: 5.85GHz -- 6.75GHz

Downlink: 3.4GHz – 4.2GHz

Local frequency: 2.225GHz

Ku-band frequency

Uplink: 14.0GHz – 14.5GHz

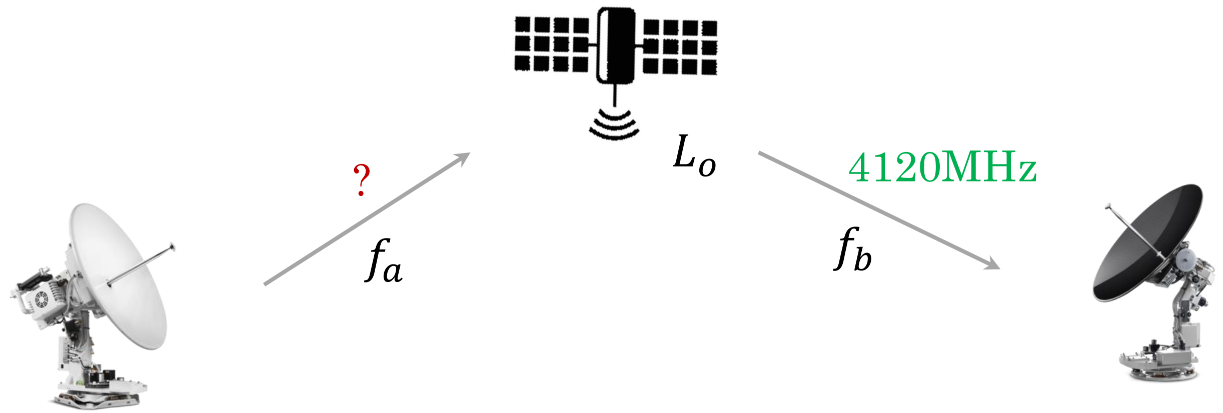
Downlink: 11.7GHz – 12.2GHz Local frequency:1.748GHz,1.750GHz

Ka-band frequency

Uplink: 27.5GHz – 31.0GHz

Downlink: 17.1GHz – 21.2GHz Local frequency:9.80GHz

CALCULATE THE UPLINK FREQUENCY



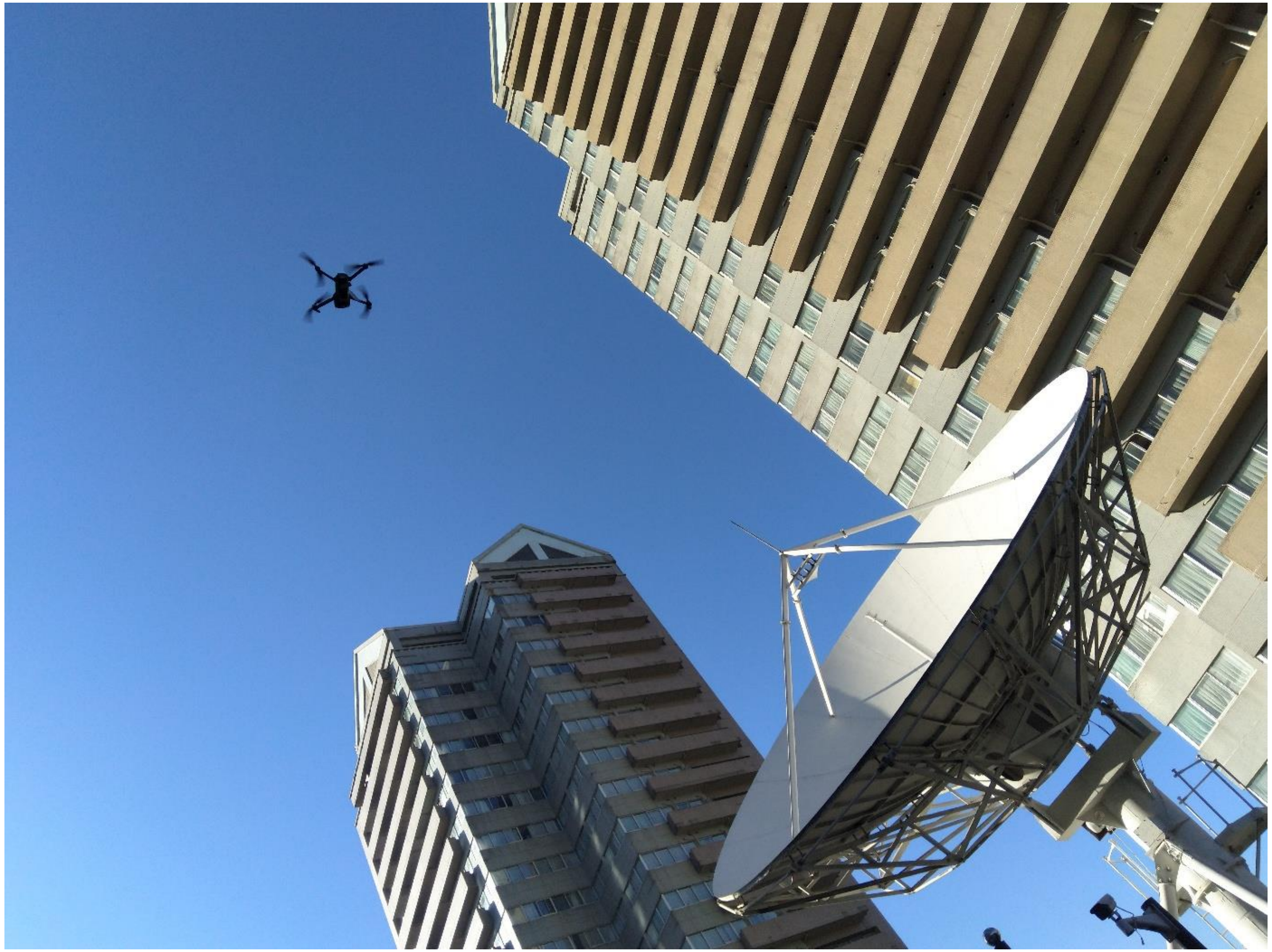
- If we know the downlink frequency. What's the uplink frequency?

$$f_b = f_a \pm L_o$$

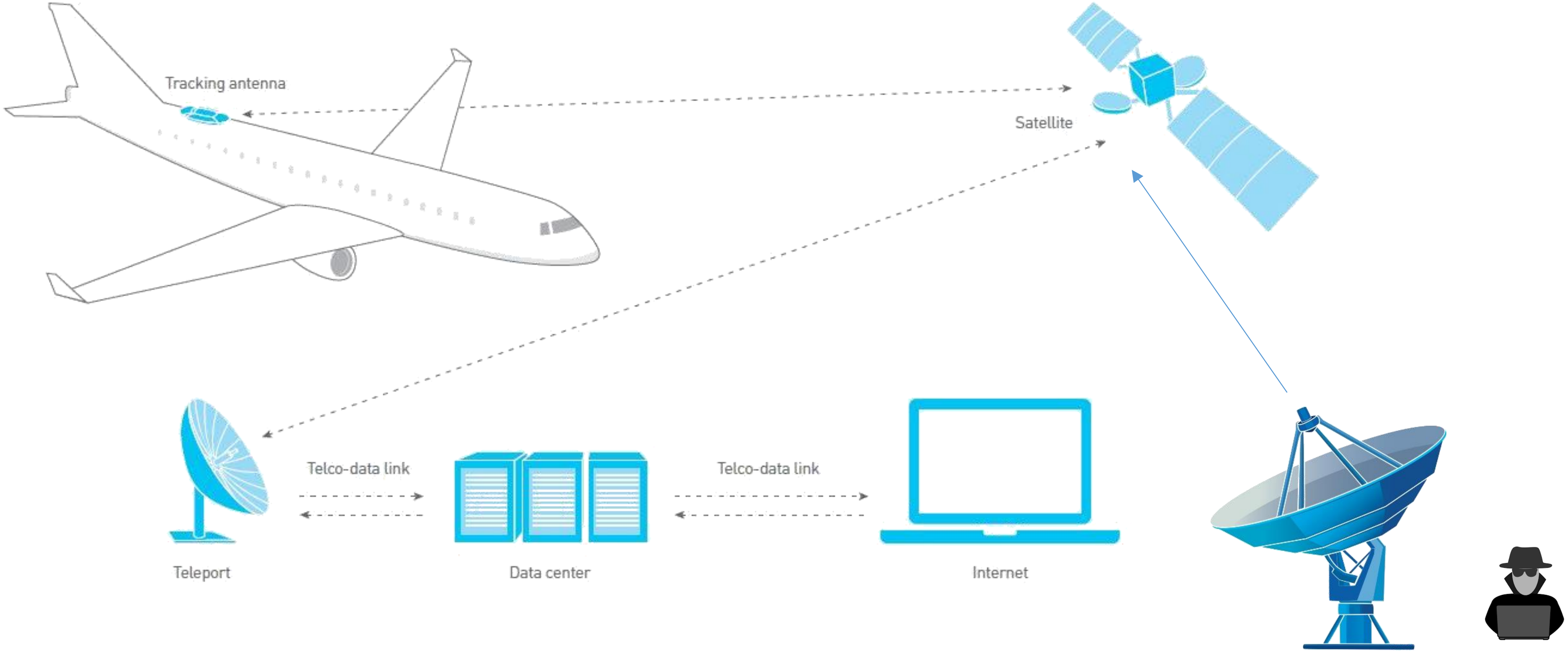
f_a, *uplink frequency*; f_b, *downlink frequency*; L_o, *local frquency*

$f_b = 4120Mhz$ => $C - band\ frequqceny$ => $L_o = 2225MHz$ => $f_a = 4120 + 2225 = 6345Mhz$

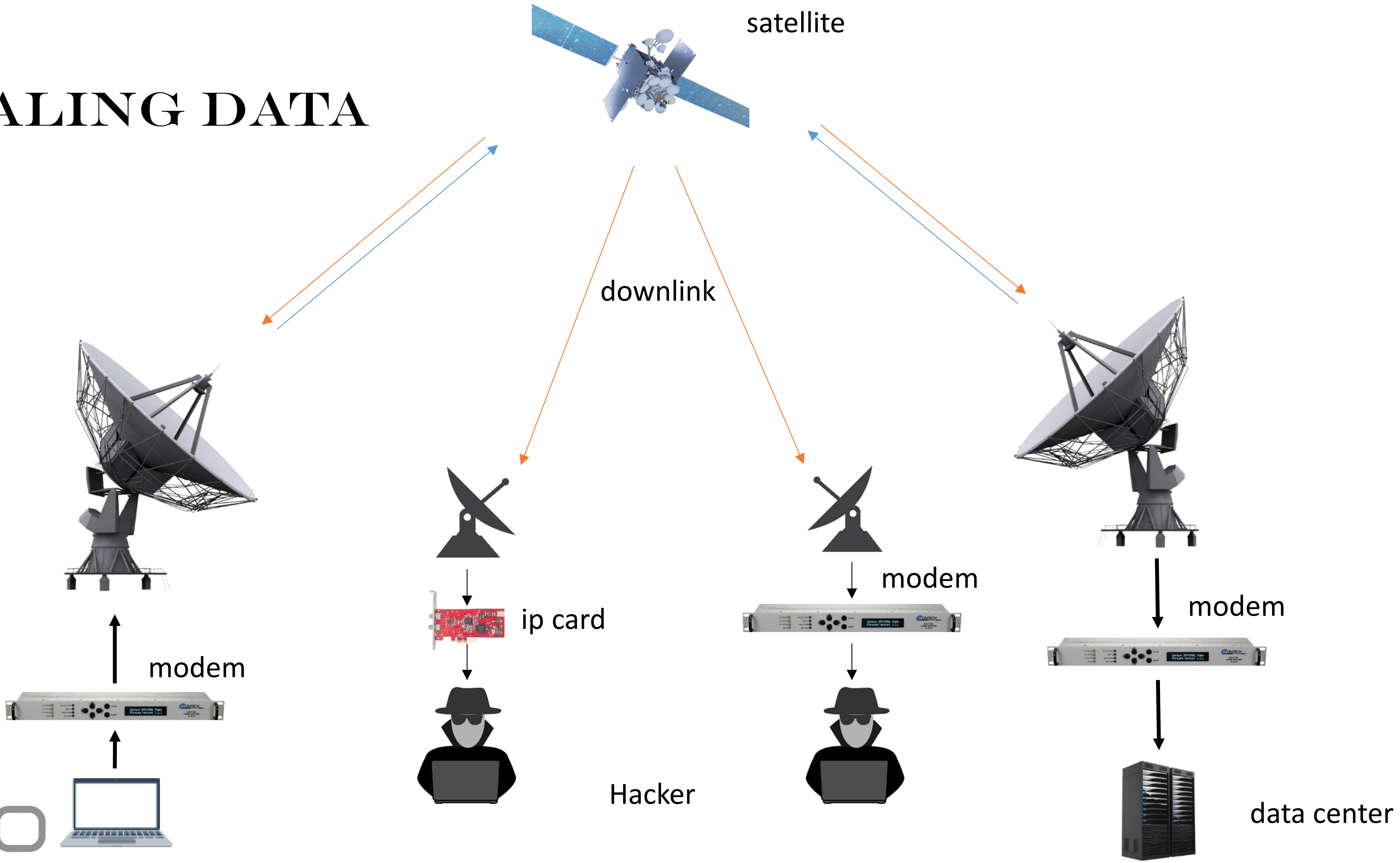
OPERATIONAL USE CASES



OPERATIONAL USE CASES



STEALING DATA



satellite

downlink

modem

ip card

modem

modem

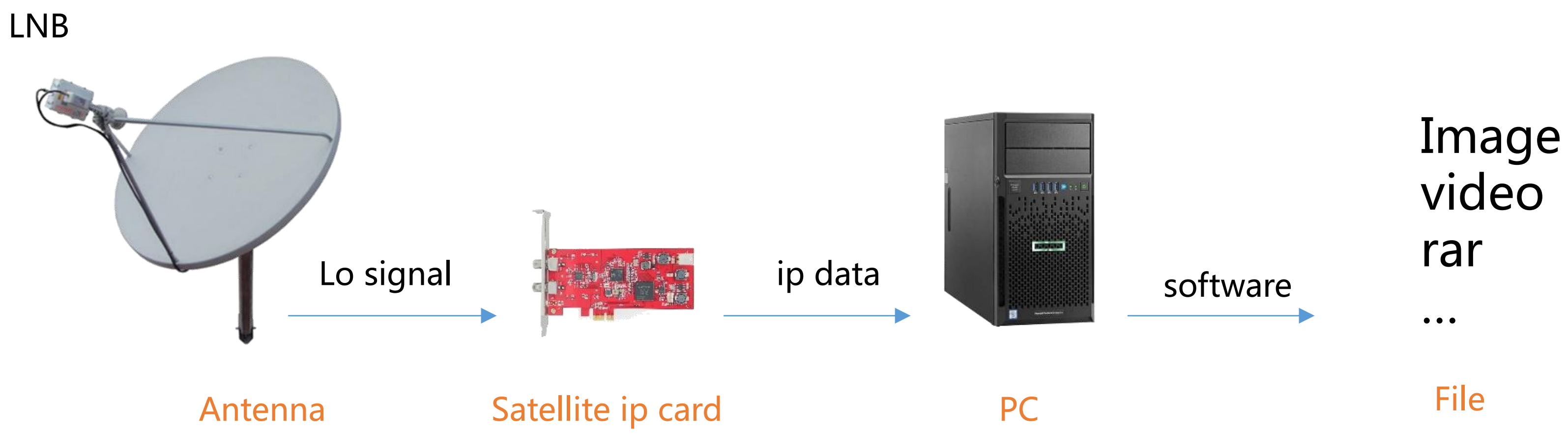
Hacker

data center

插入图片、视频、压缩包的二进制帧头

Ip sniffer software:

skynet
skygrabber
dvbsnoop



LNB

Lo signal

ip data

software

Image
video
rar
...

Antenna

Satellite ip card

PC

File

IN 2030, ALL THE ‘BENT PIP’ TRANSPONDERS DISAPPEAR.

WILL THESE THREATS DISAPPEAR TOGETHER?

NO

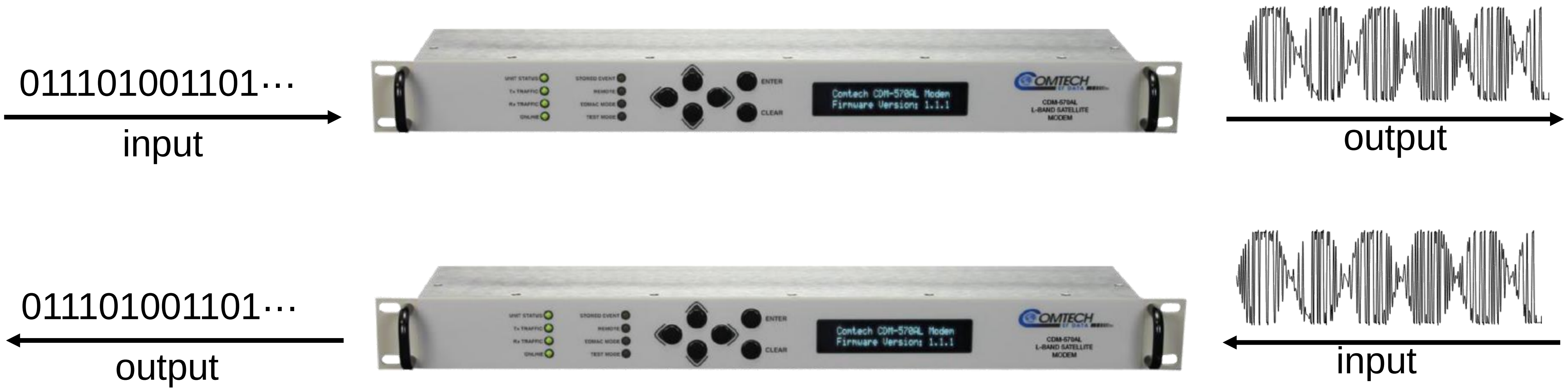
WHY CAN THESE ATTACKS SUCCEED?

IT MUST BE SATELLITE MODEMS.

SATELLITE MODEMS

Comtech EF Data
ORBCOMM
ViaSat
Gilat Satellite Networks
Novelsat
Newtec
Datum Systems
Teledyne Paradise Datacom
Hughes Network Systems
Advantech Wireless
WORK Microwave
Ayecka Communication Systems
Amplus Communication

SATELLITE MODEM



011101001101···

input

output

011101001101···

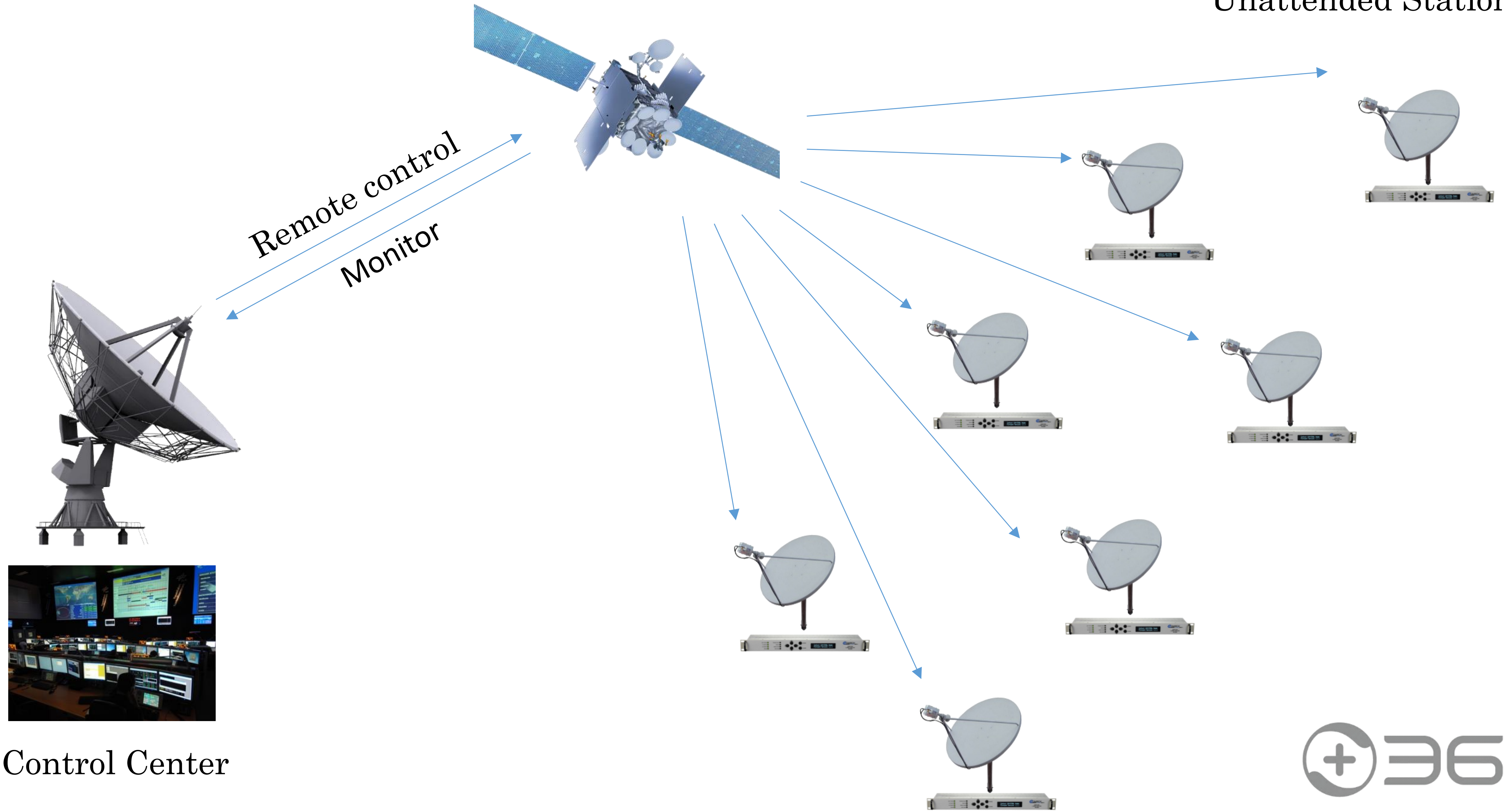
output

input

Data are transferred to a modem from data terminal equipment (e.g. a computer).
In most cases frequency has to be converted using an upconverter before amplification and transmission.

Similarly, a signal received from a satellite is firstly downconverted (this is done by a Low-noise block converter - LNB), then demodulated by a modem, and at last handled by data terminal equipment.

REMOTE CONTROL FUNCTION



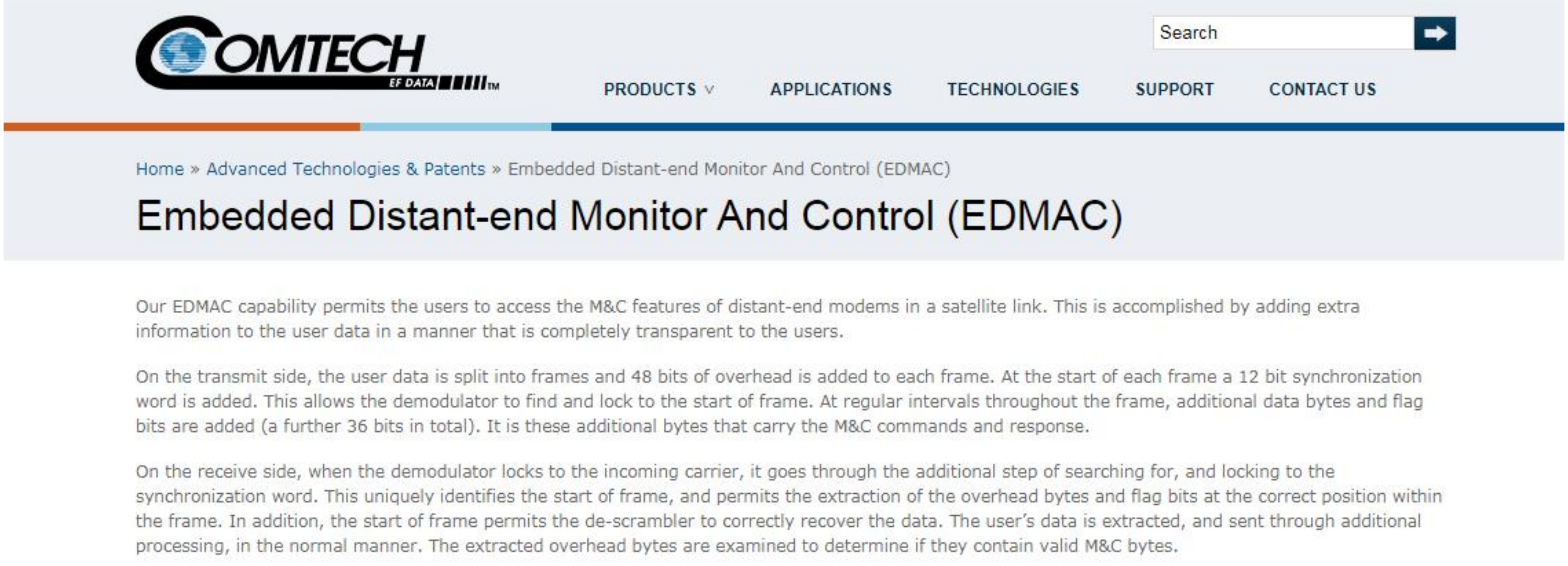
Unattended Stations

Remote control

Monitor

Control Center

EDMAC OF COMTECH



COMTECH EF DATA
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APPLICATIONS
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Home » Advanced Technologies & Patents » Embedded Distant-end Monitor And Control (EDMAC)

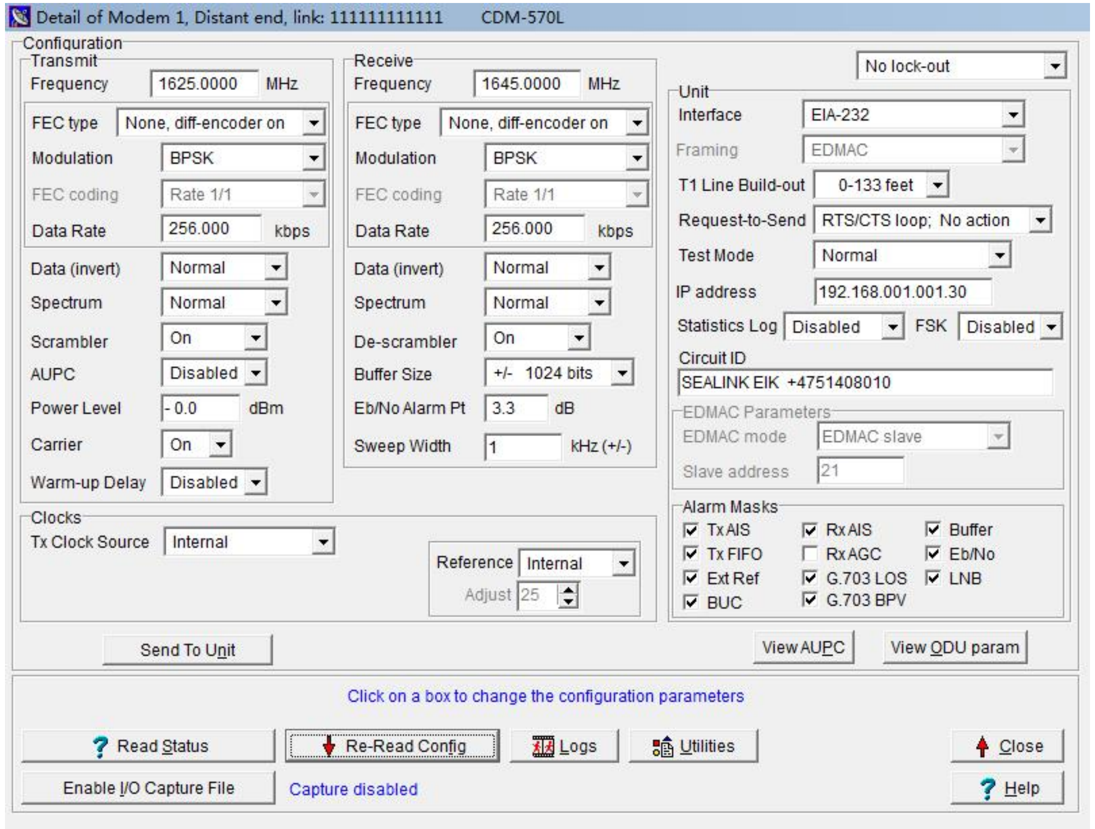
Embedded Distant-end Monitor And Control (EDMAC)

Our EDMAC capability permits the users to access the M&C features of distant-end modems in a satellite link. This is accomplished by adding extra information to the user data in a manner that is completely transparent to the users.

On the transmit side, the user data is split into frames and 48 bits of overhead is added to each frame. At the start of each frame a 12 bit synchronization word is added. This allows the demodulator to find and lock to the start of frame. At regular intervals throughout the frame, additional data bytes and flag bits are added (a further 36 bits in total). It is these additional bytes that carry the M&C commands and response.

On the receive side, when the demodulator locks to the incoming carrier, it goes through the additional step of searching for, and locking to the synchronization word. This uniquely identifies the start of frame, and permits the extraction of the overhead bytes and flag bits at the correct position within the frame. In addition, the start of frame permits the de-scrambler to correctly recover the data. The user's data is extracted, and sent through additional processing, in the normal manner. The extracted overhead bytes are examined to determine if they contain valid M&C bytes.

EMBEDDED DISTANT-END MONITOR AND CONTROL (EDMAC)



Detail of Modem 1, Distant end, link: 111111111111 CDM-570L

Configuration

Transmit

Frequency	1625.0000	MHz
FEC type	None, diff-encoder on	
Modulation	BPSK	
FEC coding	Rate 1/1	
Data Rate	256.000	kbps
Data (invert)	Normal	
Spectrum	Normal	
Scrambler	On	
AUPC	Disabled	
Power Level	- 0.0	dBm
Carrier	On	
Warm-up Delay	Disabled	

Receive

Frequency	1645.0000	MHz
FEC type	None, diff-encoder on	
Modulation	BPSK	
FEC coding	Rate 1/1	
Data Rate	256.000	kbps
Data (invert)	Normal	
Spectrum	Normal	
De-scrambler	On	
Buffer Size	+/- 1024 bits	
Eb/No Alarm Pt	3.3	dB
Sweep Width	1	kHz (+/-)

Clocks

Tx Clock Source	Internal
Reference	Internal
Adjust	25

No lock-out

Unit

Interface	EIA-232
Framing	EDMAC
T1 Line Build-out	0-133 feet
Request-to-Send	RTS/CTS loop; No action
Test Mode	Normal
IP address	192.168.001.001.30
Statistics Log	Disabled
FSK	Disabled
Circuit ID	SEALINK EIK +4751408010

EDMAC Parameters

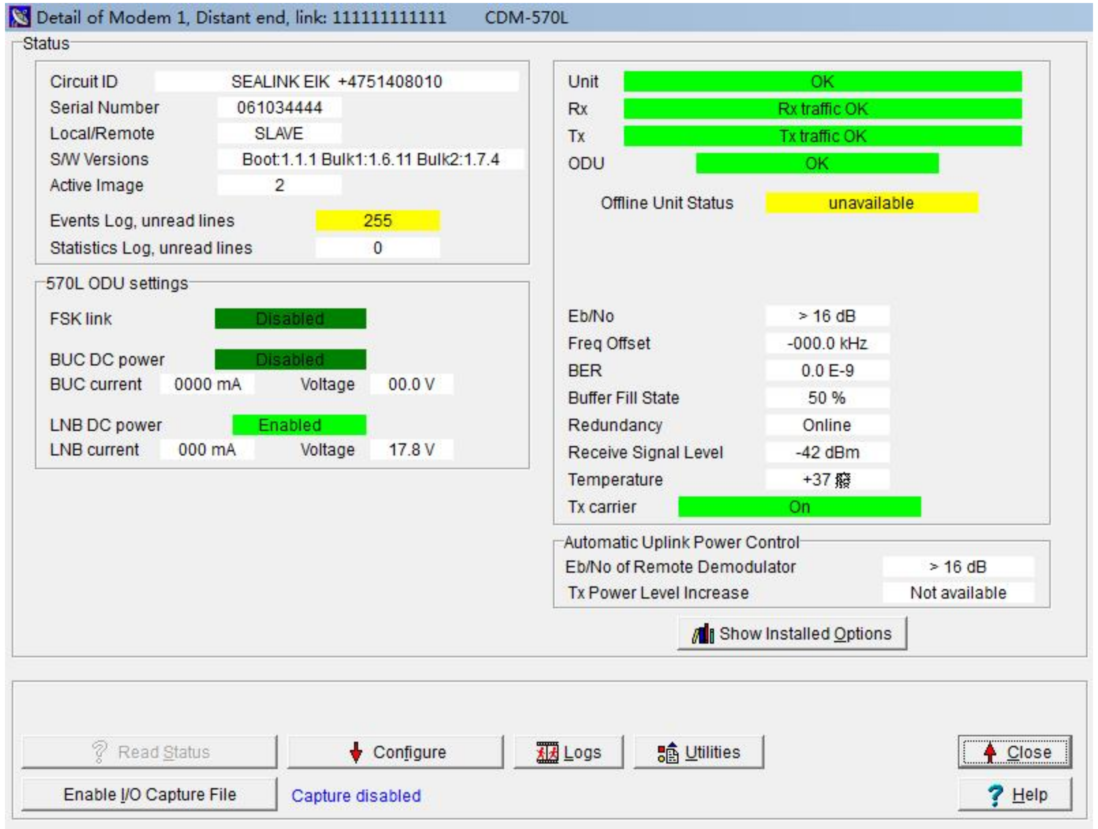
EDMAC mode	EDMAC slave
Slave address	21

Alarm Masks

☑ Tx AIS	☑ Rx AIS	☑ Buffer
☑ Tx FIFO	☐ Rx AGC	☑ Eb/No
☑ Ext Ref	☑ G.703 LOS	☑ LNB
☑ BUC	☑ G.703 BPV	

Click on a box to change the configuration parameters

Capture disabled



Detail of Modem 1, Distant end, link: 111111111111 CDM-570L

Status

Circuit ID	SEALINK EIK +4751408010
Serial Number	061034444
Local/Remote	SLAVE
S/W Versions	Boot:1.1.1 Bulk1:1.6.11 Bulk2:1.7.4
Active Image	2
Events Log, unread lines	255
Statistics Log, unread lines	0

570L ODU settings

FSK link	Disabled		
BUC DC power	Disabled		
BUC current	0000 mA	Voltage	00.0 V
LNB DC power	Enabled		
LNB current	000 mA	Voltage	17.8 V

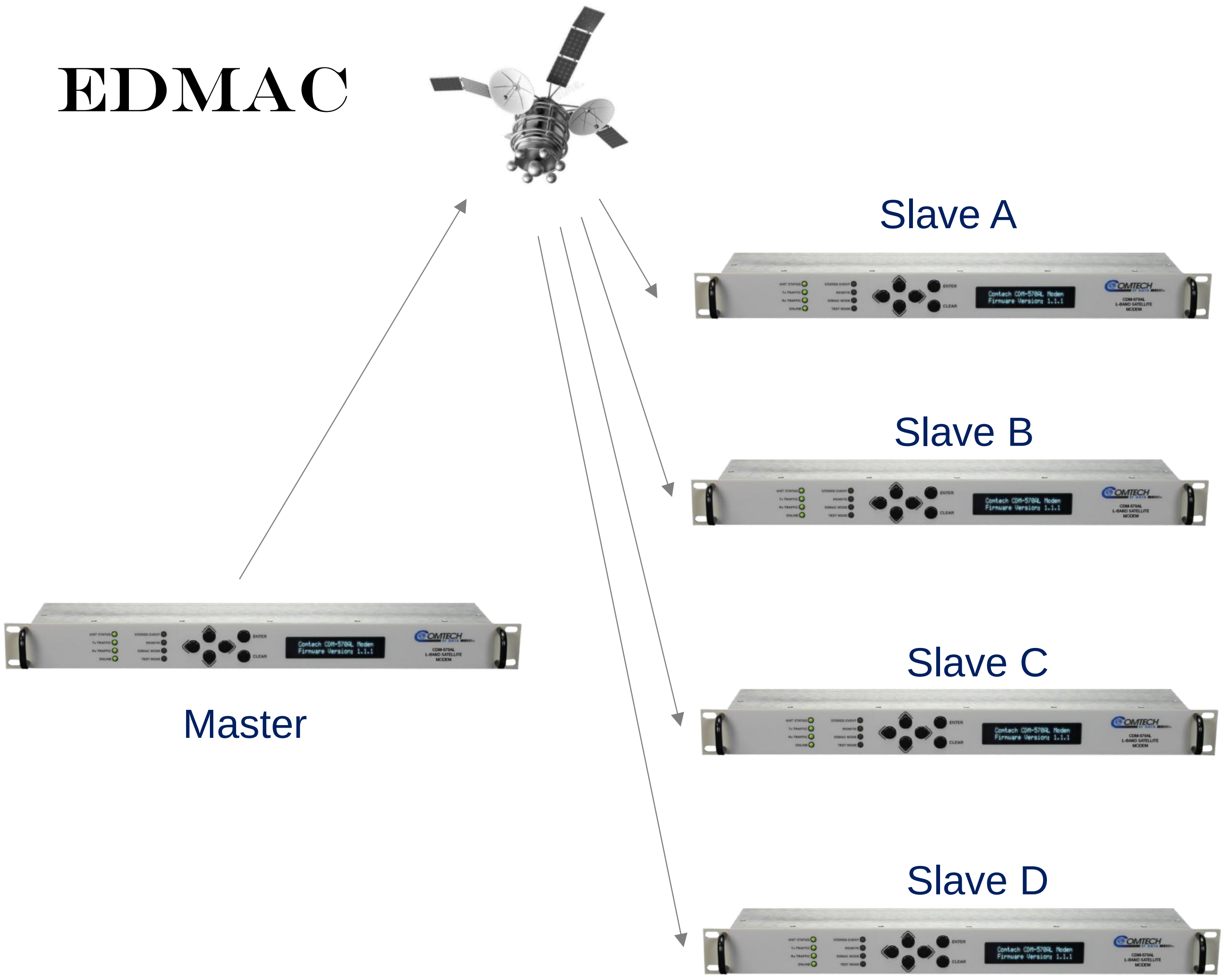
Unit	OK
Rx	Rx traffic OK
Tx	Tx traffic OK
ODU	OK
Offline Unit Status	unavailable
Eb/No	> 16 dB
Freq Offset	-000.0 kHz
BER	0.0 E-9
Buffer Fill State	50 %
Redundancy	Online
Receive Signal Level	-42 dBm
Temperature	+37 癈
Tx carrier	On

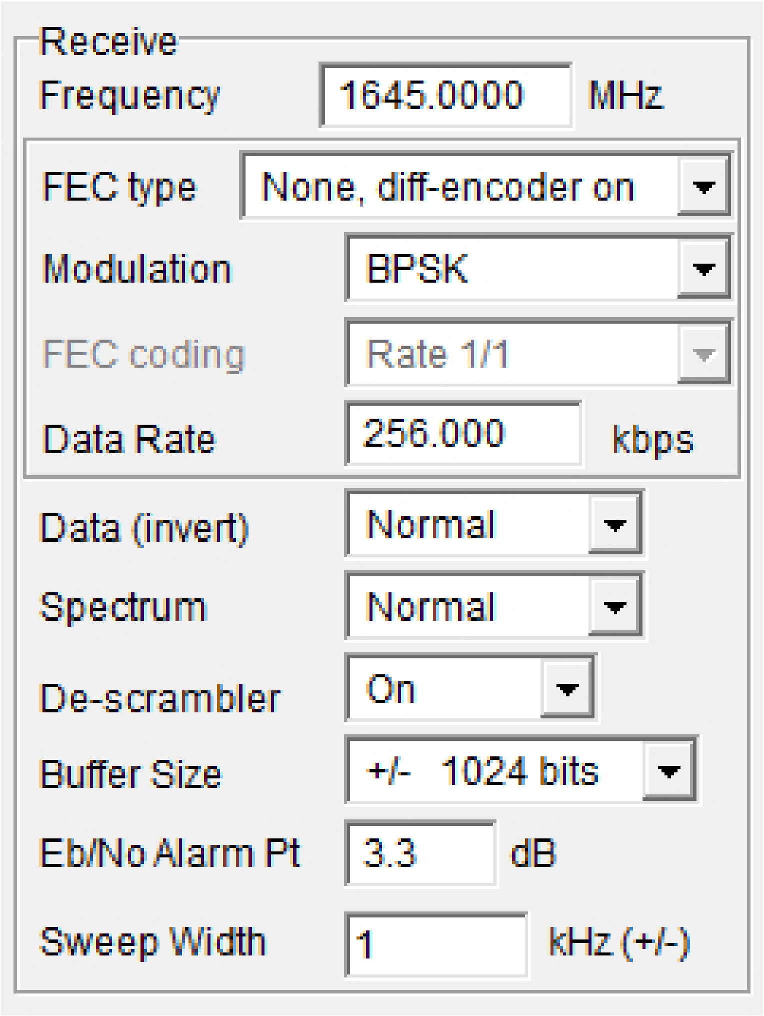
Automatic Uplink Power Control

Eb/No of Remote Demodulator	> 16 dB
Tx Power Level Increase	Not available

Capture disabled

EDMAC




Receive

Frequency 1645.0000 MHz

FEC type None, diff-encoder on

Modulation BPSK

FEC coding Rate 1/1

Data Rate 256.000 kbps

Data (invert) Normal

Spectrum Normal

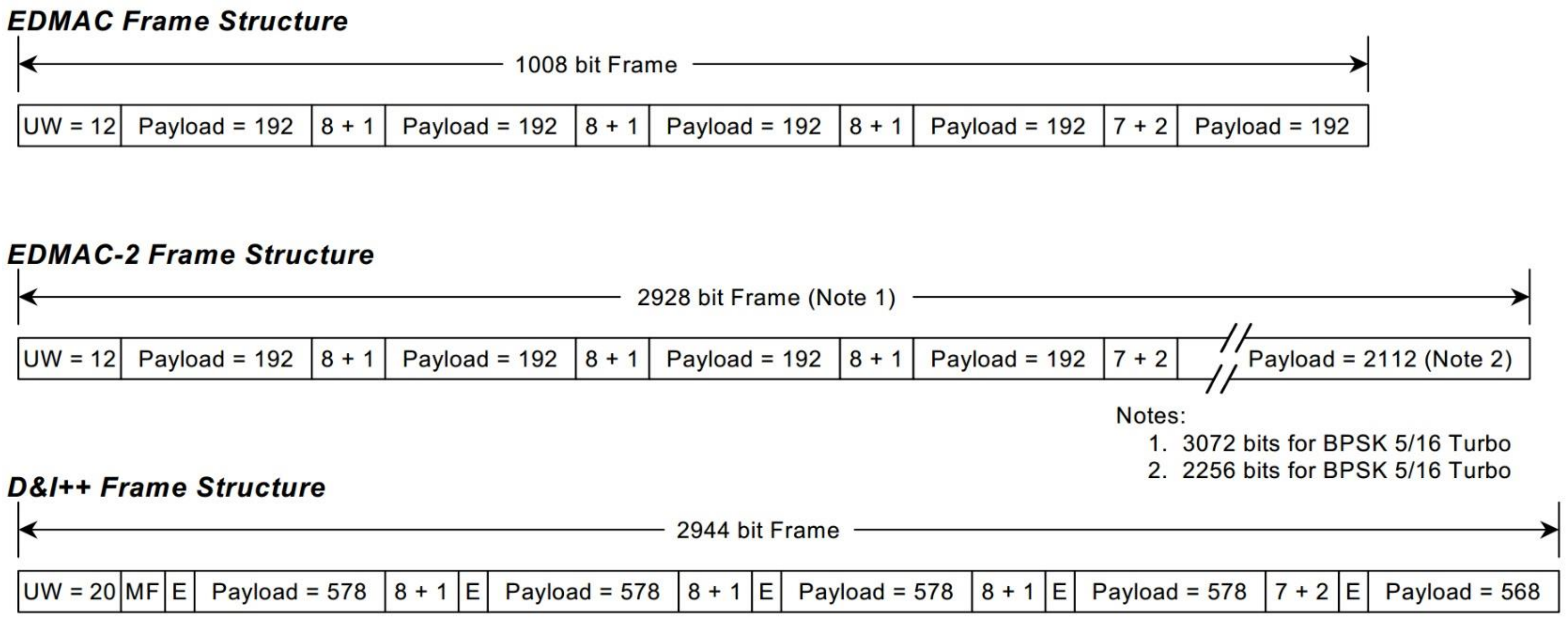
De-scrambler On

Buffer Size +/- 1024 bits

Eb/No Alarm Pt 3.3 dB

Sweep Width 1 kHz (+/-)

EDMAC FRAME STRUCTURE



EDMAC Frame Structure

1008 bit Frame

UW = 12	Payload = 192	8 + 1	Payload = 192	8 + 1	Payload = 192	8 + 1	Payload = 192	7 + 2	Payload = 192

EDMAC-2 Frame Structure

2928 bit Frame (Note 1)

UW = 12	Payload = 192	8 + 1	Payload = 192	8 + 1	Payload = 192	8 + 1	Payload = 192	7 + 2	Payload = 2112 (Note 2)

Notes:
1. 3072 bits for BPSK 5/16 Turbo
2. 2256 bits for BPSK 5/16 Turbo

D&I++ Frame Structure

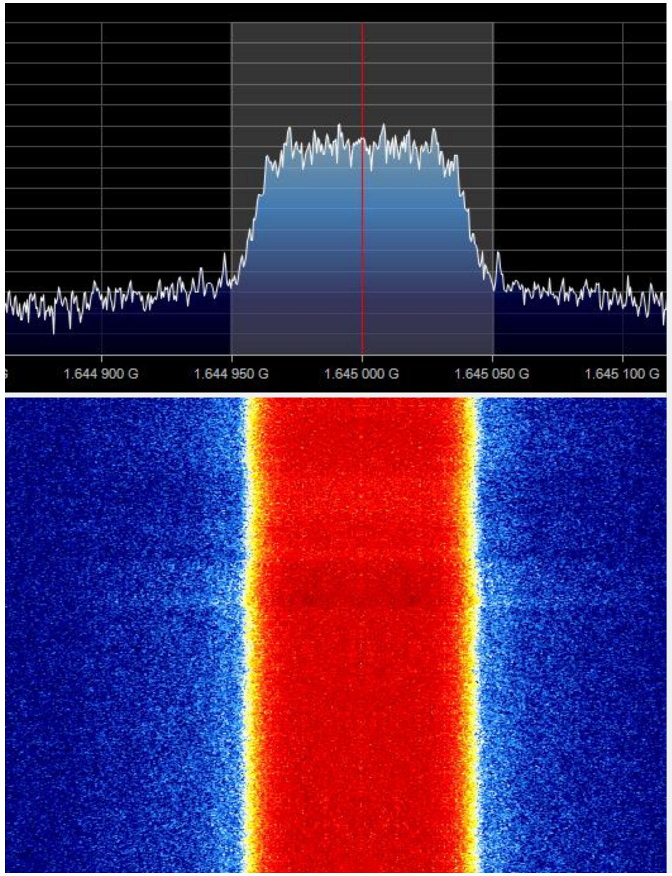
2944 bit Frame

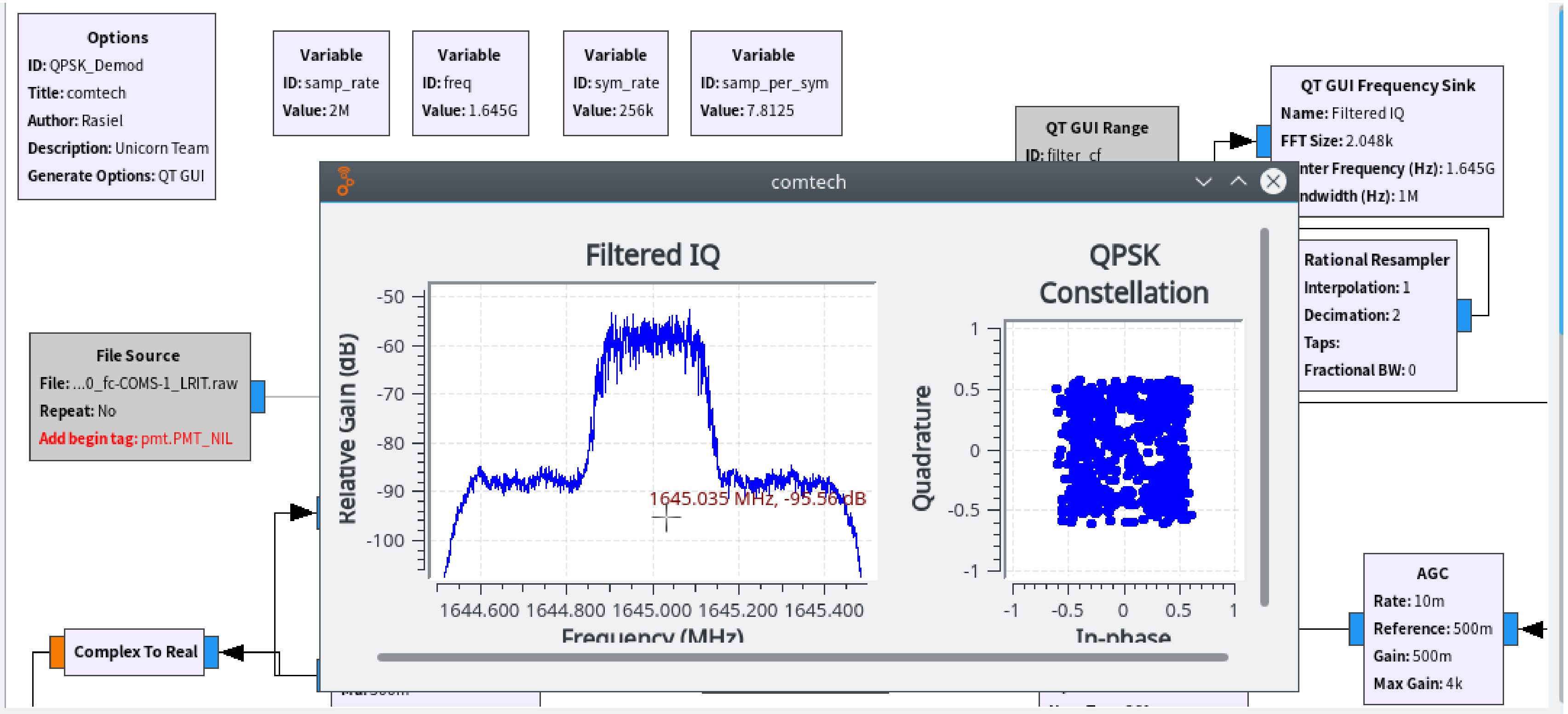
UW = 20	MF	E	Payload = 578	8 + 1	E	Payload = 578	8 + 1	E	Payload = 578	8 + 1	E	Payload = 578	7 + 2	E	Payload = 568

Item	Description
UW	Unique Word
Payload	User Data
8 + 1	EDMAC Data + 1 Flag bit
7 + 1	AUPC Data + 2 Flag bits
MF	Multi-frame Count, 3 bits
E	ESC Channel, 1 bit

If we can reverse the EDMAC command, we can
control the modem using EDMAC through the air

QPSK





Options
ID: QPSK_Demod
Title: comtech
Author: Rasiel
Description: Unicorn Team
Generate Options: QT GUI

Variable
ID: samp_rate
Value: 2M

Variable
ID: freq
Value: 1.645G

Variable
ID: sym_rate
Value: 256k

Variable
ID: samp_per_sym
Value: 7.8125

QT GUI Range
ID: filter_cf

QT GUI Frequency Sink
Name: Filtered IQ
FFT Size: 2.048k
nter Frequency (Hz): 1.645G
ndwidth (Hz): 1M

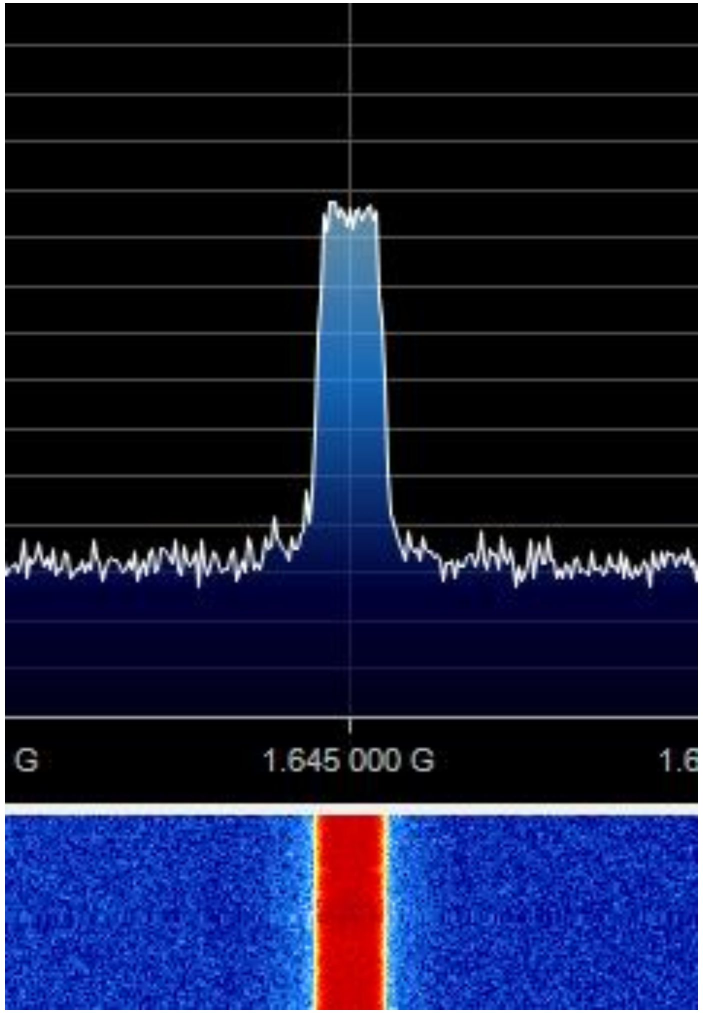
Rational Resampler
Interpolation: 1
Decimation: 2
Taps:
Fractional BW: 0

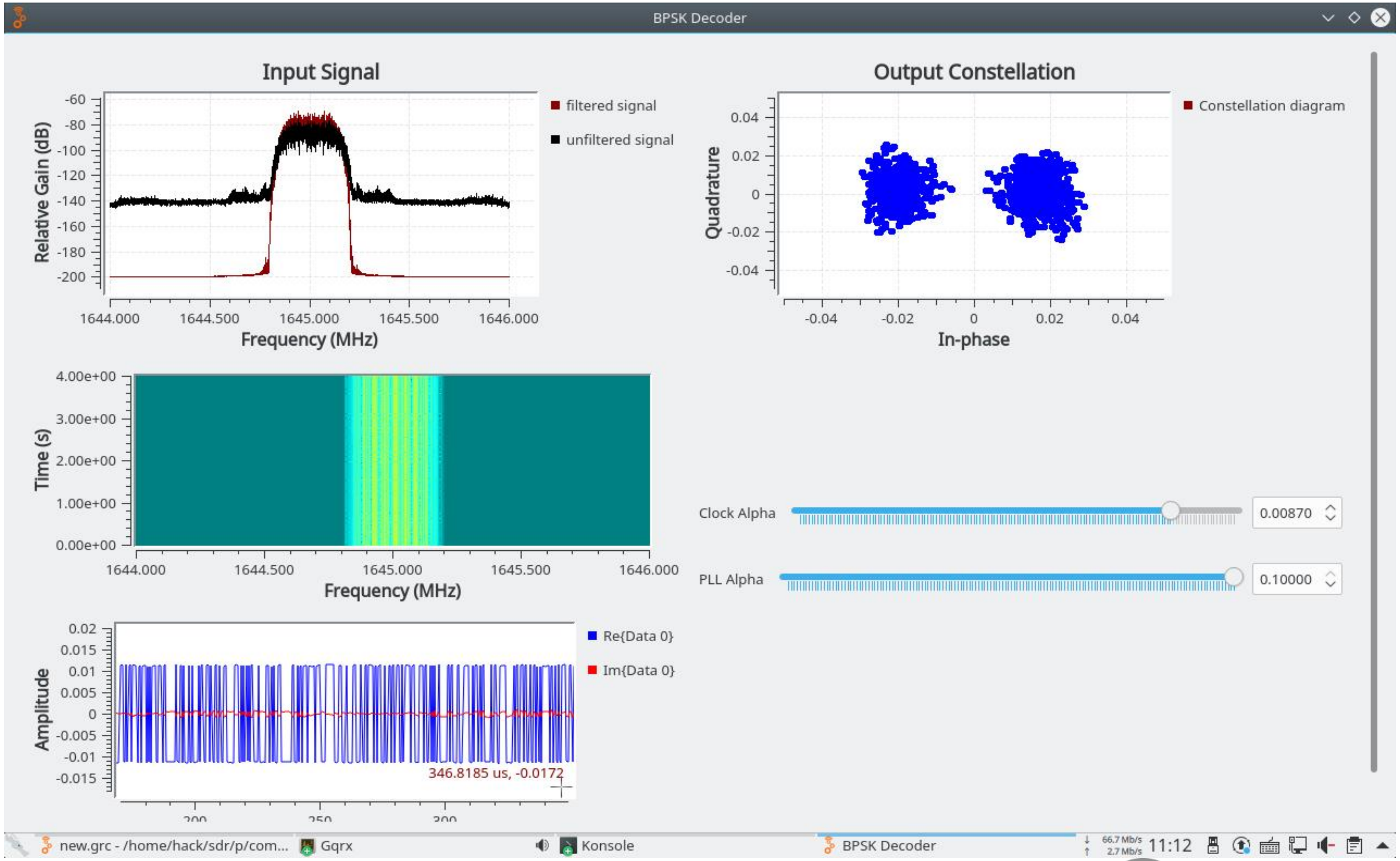
File Source
File: ...0_fc-COMS-1_LRIT.raw
Repeat: No
Add begin tag: pmt.PMT_NIL

Complex To Real

AGC
Rate: 10m
Reference: 500m
Gain: 500m
Max Gain: 4k

BPSK

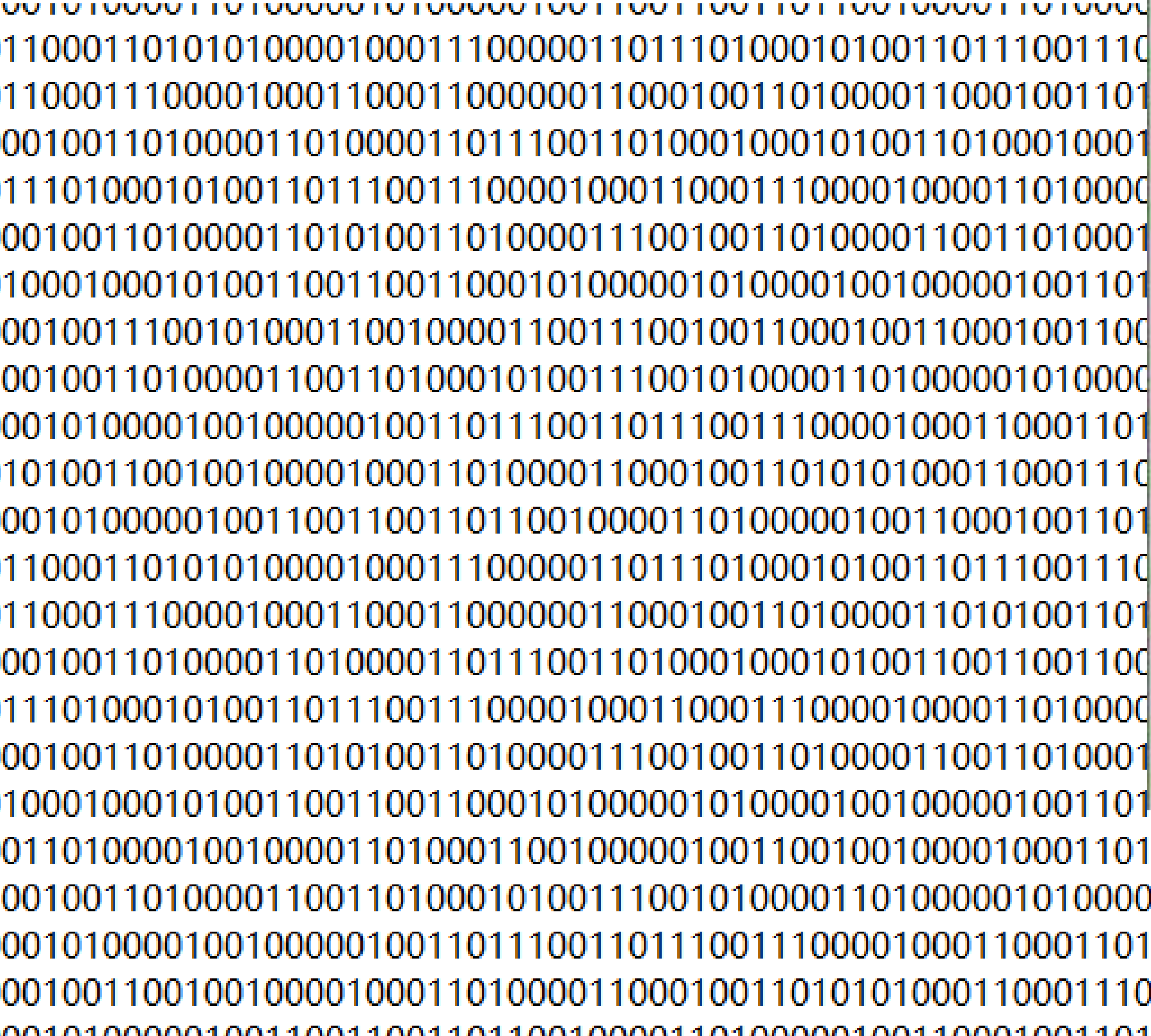




Clock Alpha 0.00870

PLL Alpha 0.10000

DECODED DATA



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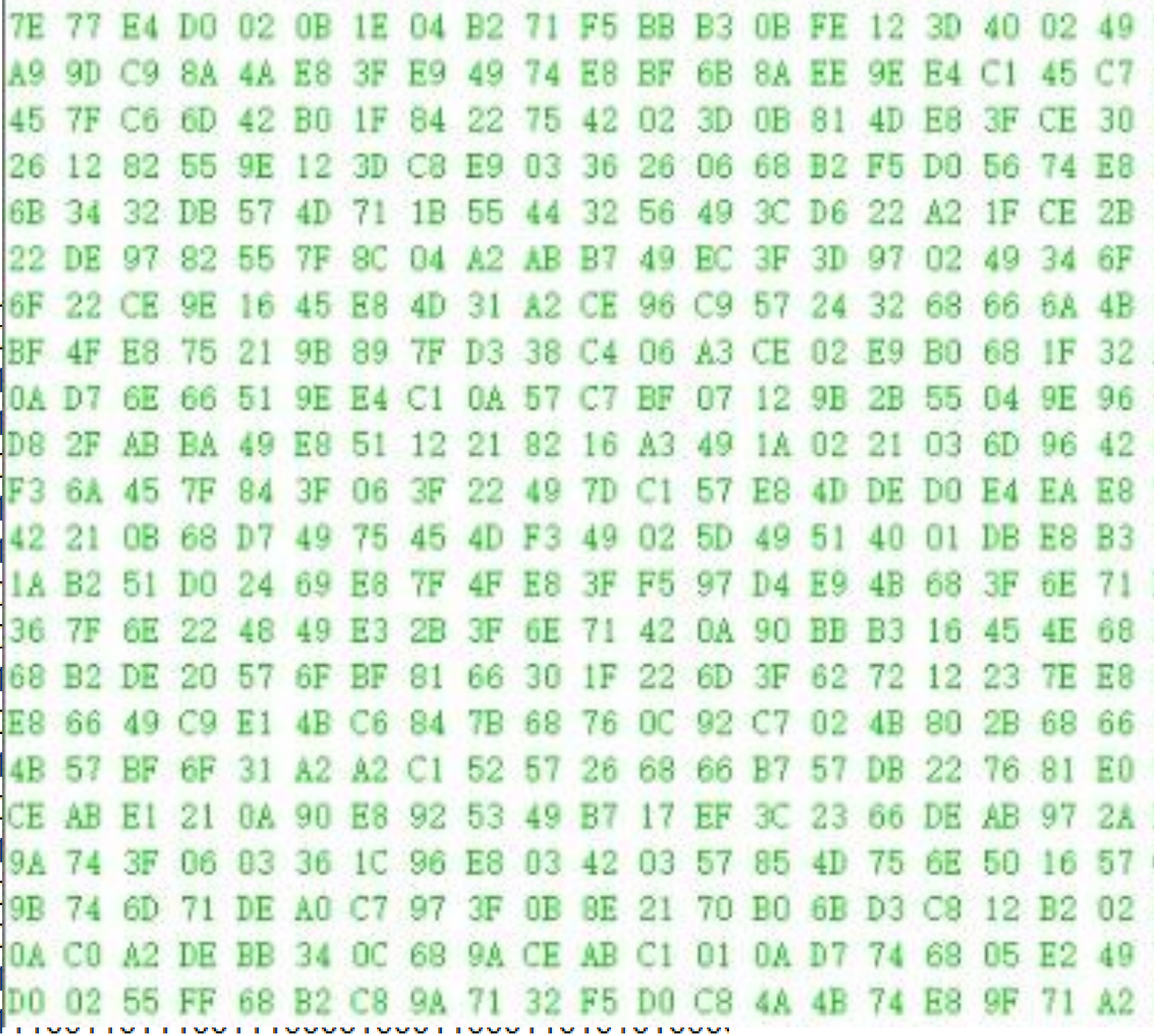

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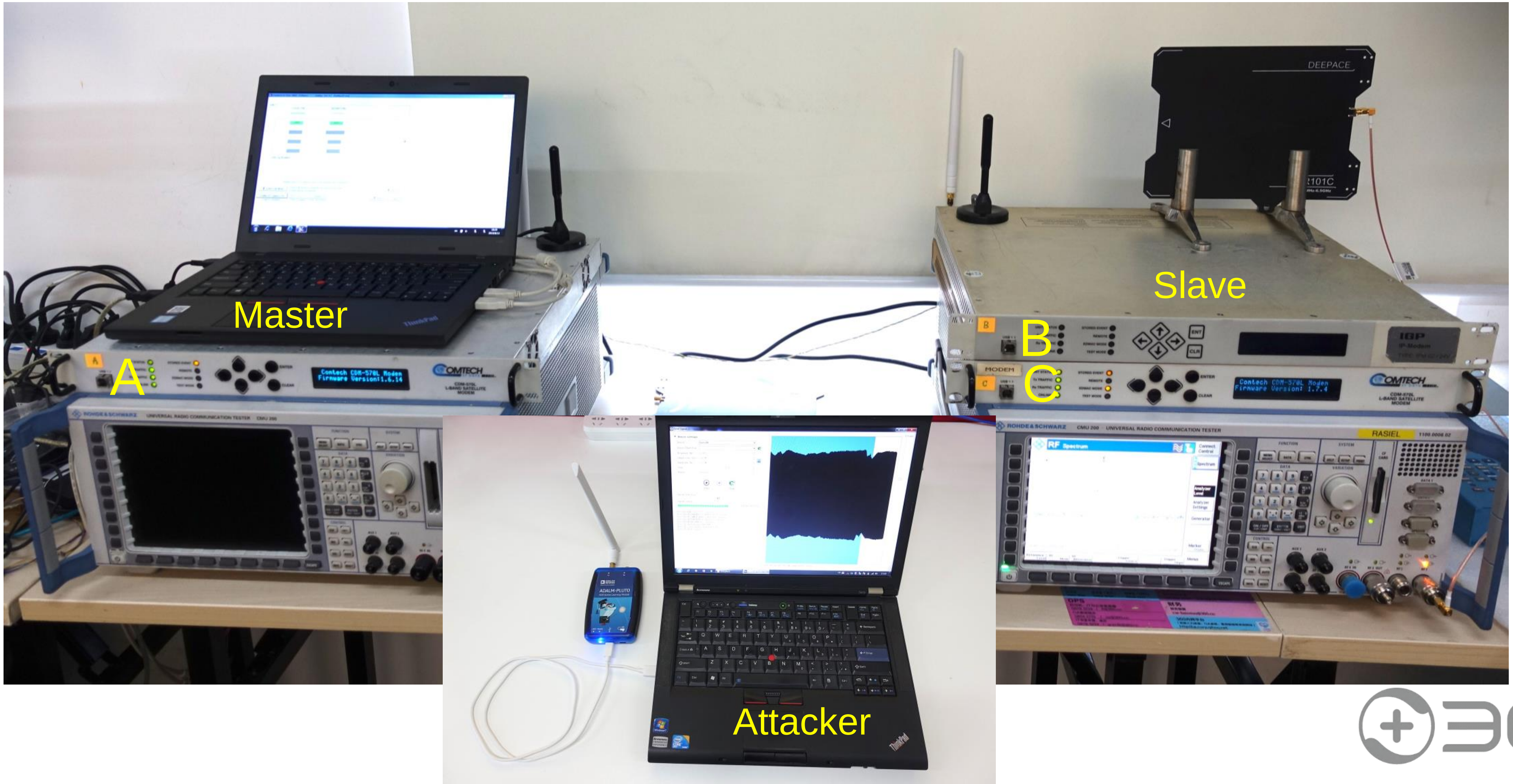
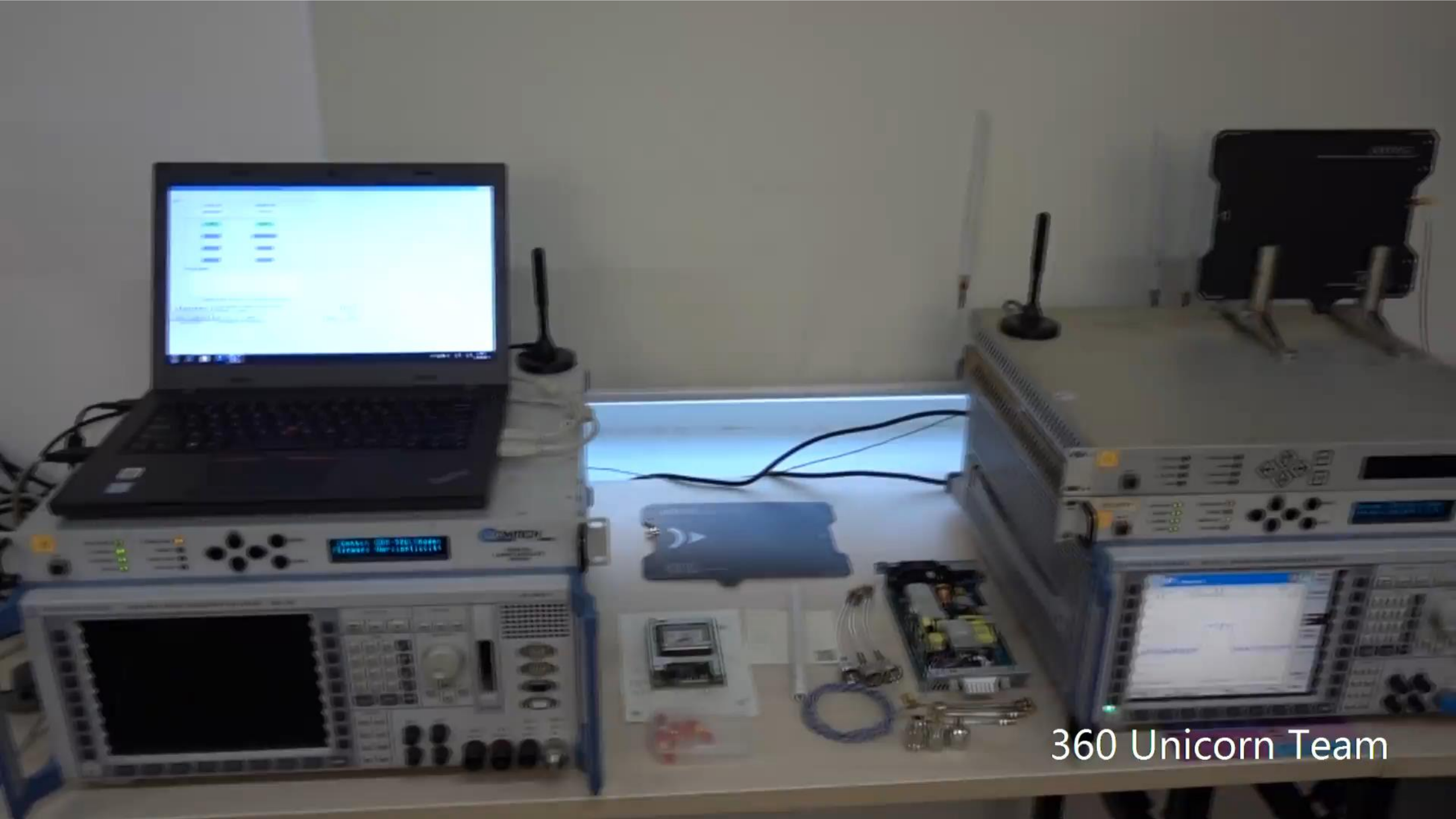
45 7F C6 6D 42 B0 1F 84 22 75 42 02 3D 0B 81 4D E8 3F CE 30
26 12 82 55 9E 12 3D C8 E9 03 36 26 06 68 B2 F5 D0 56 74 E8
6B 34 32 DB 57 4D 71 1B 55 44 32 56 49 3C D6 22 A2 1F CE 2B
22 DE 97 82 55 7F 8C 04 A2 AB B7 49 BC 3F 3D 97 02 49 34 6F
6F 22 CE 9E 16 45 E8 4D 31 A2 CE 96 C9 57 24 32 68 66 6A 4B
BF 4F E8 75 21 9B 89 7F D3 38 C4 06 A3 CE 02 E9 B0 68 1F 32
0A D7 6E 66 51 9E E4 C1 0A 57 C7 BF 07 12 9B 2B 55 04 9E 96
D8 2F AB BA 49 E8 51 12 21 82 16 A3 49 1A 02 21 03 6D 96 42
F3 6A 45 7F 84 3F 06 3F 22 49 7D C1 57 E8 4D DE D0 E4 EA E8
42 21 0B 68 D7 49 75 45 4D F3 49 02 5D 49 51 40 01 DB E8 B3
1A B2 51 D0 24 69 E8 7F 4F E8 3F F5 97 D4 E9 4B 68 3F 6E 71
36 7F 6E 22 48 49 E3 2B 3F 6E 71 42 0A 90 BB B3 16 45 4E 68
68 B2 DE 20 57 6F BF 81 66 30 1F 22 6D 3F 62 72 12 23 7E E8
E8 66 49 C9 E1 4B C6 84 7B 68 76 0C 92 C7 02 4B 80 2B 68 66
4B 57 BF 6F 31 A2 A2 C1 52 57 26 68 66 B7 57 DB 22 76 81 E0
CE AB E1 21 0A 90 E8 92 53 49 B7 17 EF 3C 23 66 DE AB 97 2A
9A 74 3F 06 03 36 1C 96 E8 03 42 03 57 85 4D 75 6E 50 16 57
9B 74 6D 71 DE A0 C7 97 3F 0B 8E 21 70 B0 6B D3 C8 12 B2 02
0A C0 A2 DE BB 34 0C 68 9A CE AB C1 01 0A D7 74 68 05 E2 49
D0 02 55 FF 68 B2 C8 9A 71 32 F5 D0 C8 4A 4B 74 E8 9F 71 A2
```

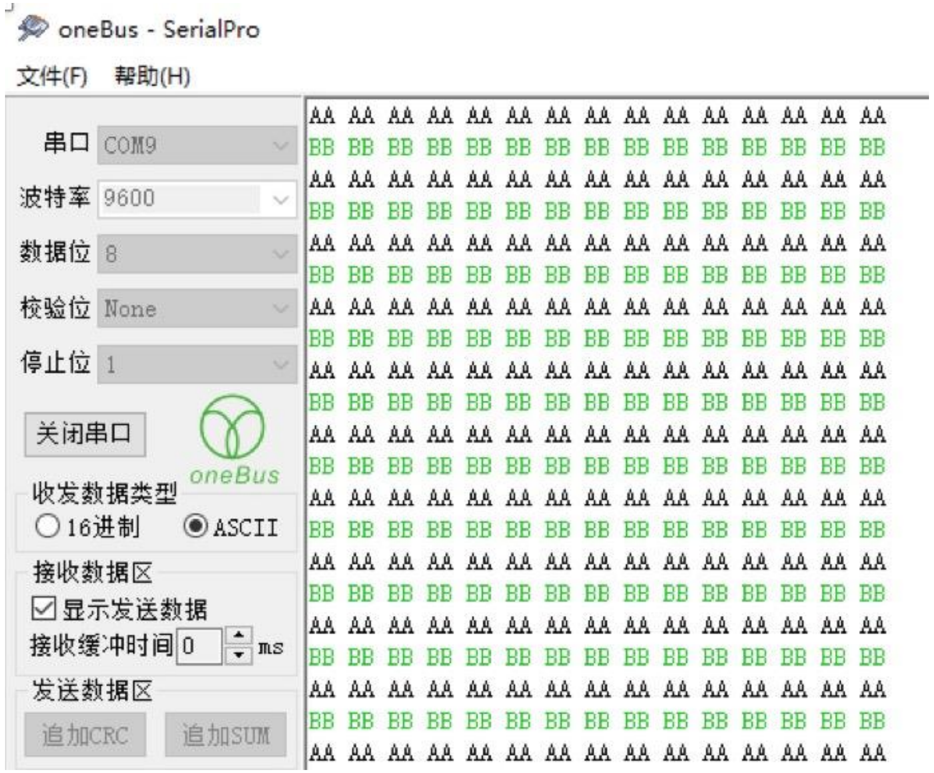
ATTACK SCENARIO





360 Unicorn Team

NORMAL



串口 COM9

波特率 9600

数据位 8

校验位 None

停止位 1

收发数据类型
○ 16进制 ● ASCII

接收数据区
☑ 显示发送数据
接收缓冲时间 0 ms

发送数据区

```
AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA
BB BB BB BB BB BB BB BB BB BB BB BB BB BB BB
AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA
BB BB BB BB BB BB BB BB BB BB BB BB BB BB BB
AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA
BB BB BB BB BB BB BB BB BB BB BB BB BB BB BB
AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA
BB BB BB BB BB BB BB BB BB BB BB BB BB BB BB
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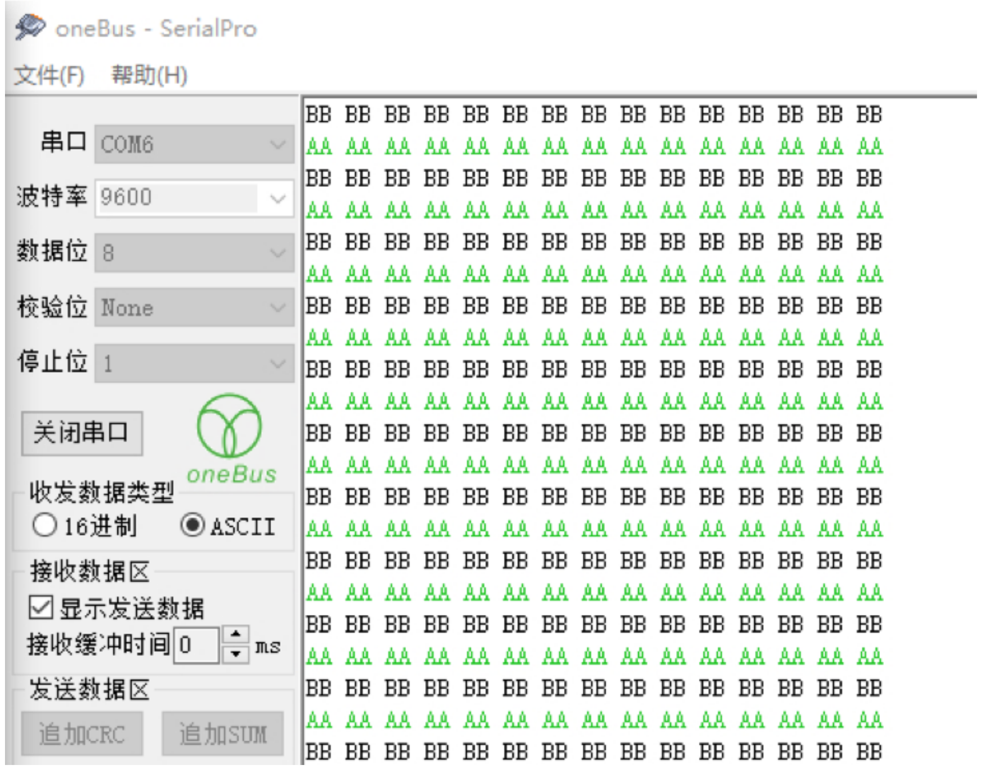
AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA
BB BB BB BB BB BB BB BB BB BB BB BB BB BB BB
AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA
```

Modem A



串口 COM6

波特率 9600

数据位 8

校验位 None

停止位 1

收发数据类型
○ 16进制 ● ASCII

接收数据区
☑ 显示发送数据
接收缓冲时间 0 ms

发送数据区

```
BB BB BB BB BB BB BB BB BB BB BB BB BB BB BB
AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA
BB BB BB BB BB BB BB BB BB BB BB BB BB BB BB
AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA
BB BB BB BB BB BB BB BB BB BB BB BB BB BB BB
AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA
BB BB BB BB BB BB BB BB BB BB BB BB BB BB BB
AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA
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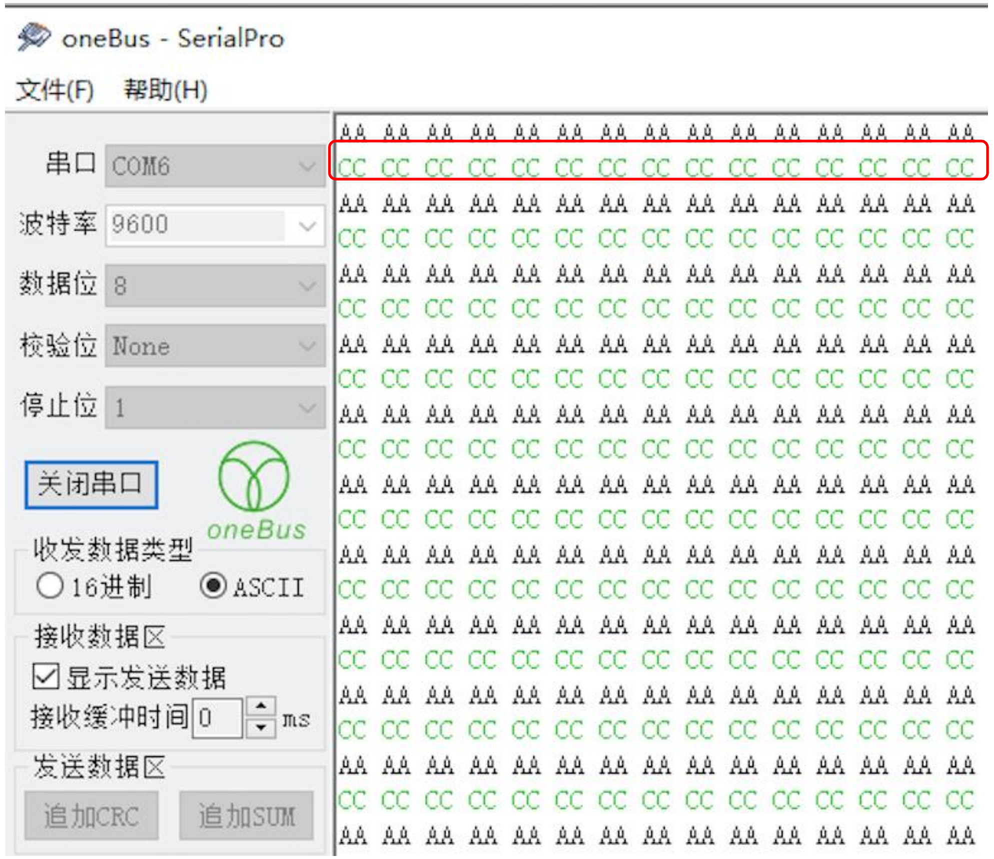
BB BB BB BB BB BB BB BB BB BB BB BB BB BB BB
AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA
BB BB BB BB BB BB BB BB BB BB BB BB BB BB BB
AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA
BB BB BB BB BB BB BB BB BB BB BB BB BB BB BB
AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA
BB BB BB BB BB BB BB BB BB BB BB BB BB BB BB
```

Modem B

Modem A sends data “A” to Modem B, and Modem B sends data “B” in response. The data received by Modem A is "B"!

BE ATTACKED…



串口 COM6

波特率 9600

数据位 8

校验位 None

停止位 1

收发数据类型 ○16进制 ●ASCII

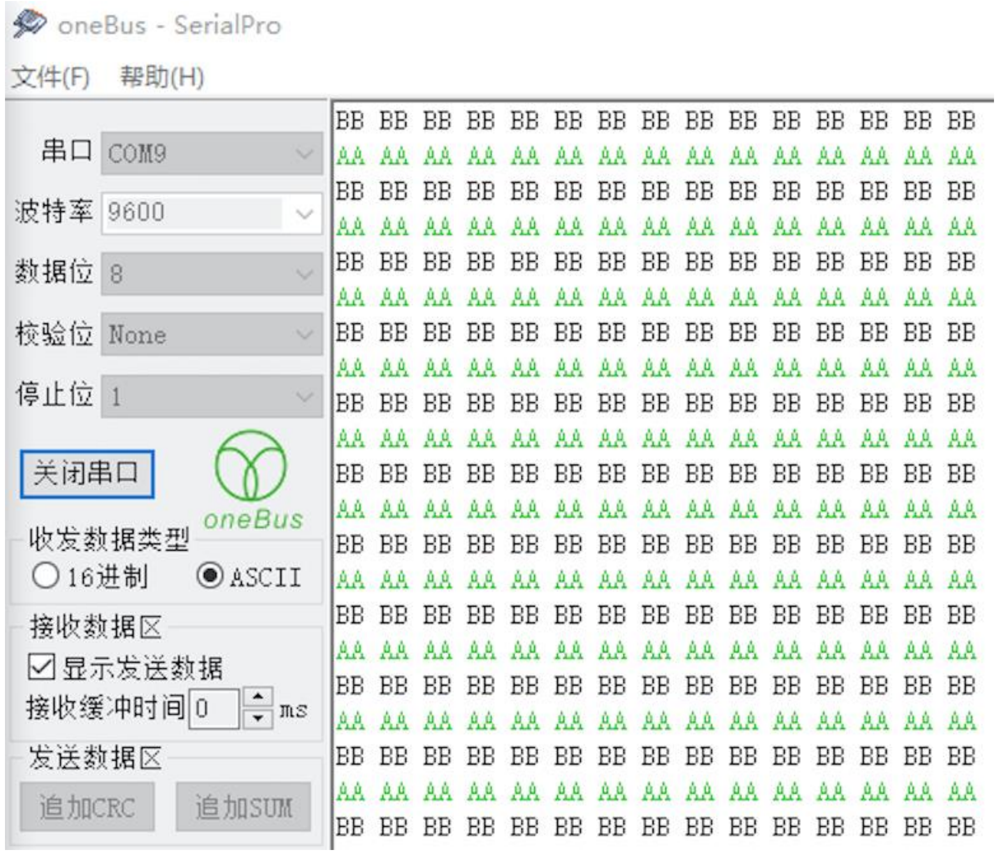
接收数据区 ☑显示发送数据

接收缓冲时间 0 ms

发送数据区

```
AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA
CC CC CC CC CC CC CC CC CC CC CC CC CC CC CC
AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA
CC CC CC CC CC CC CC CC CC CC CC CC CC CC CC
AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA
CC CC CC CC CC CC CC CC CC CC CC CC CC CC CC
AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA
CC CC CC CC CC CC CC CC CC CC CC CC CC CC CC
AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA
CC CC CC CC CC CC CC CC CC CC CC CC CC CC CC
AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA
CC CC CC CC CC CC CC CC CC CC CC CC CC CC CC
AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA
CC CC CC CC CC CC CC CC CC CC CC CC CC CC CC
AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA
CC CC CC CC CC CC CC CC CC CC CC CC CC CC CC
AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA
CC CC CC CC CC CC CC CC CC CC CC CC CC CC CC
AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA
CC CC CC CC CC CC CC CC CC CC CC CC CC CC CC
AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA
```

Modem A



串口 COM9

波特率 9600

数据位 8

校验位 None

停止位 1

收发数据类型 ○16进制 ●ASCII

接收数据区 ☑显示发送数据

接收缓冲时间 0 ms

发送数据区

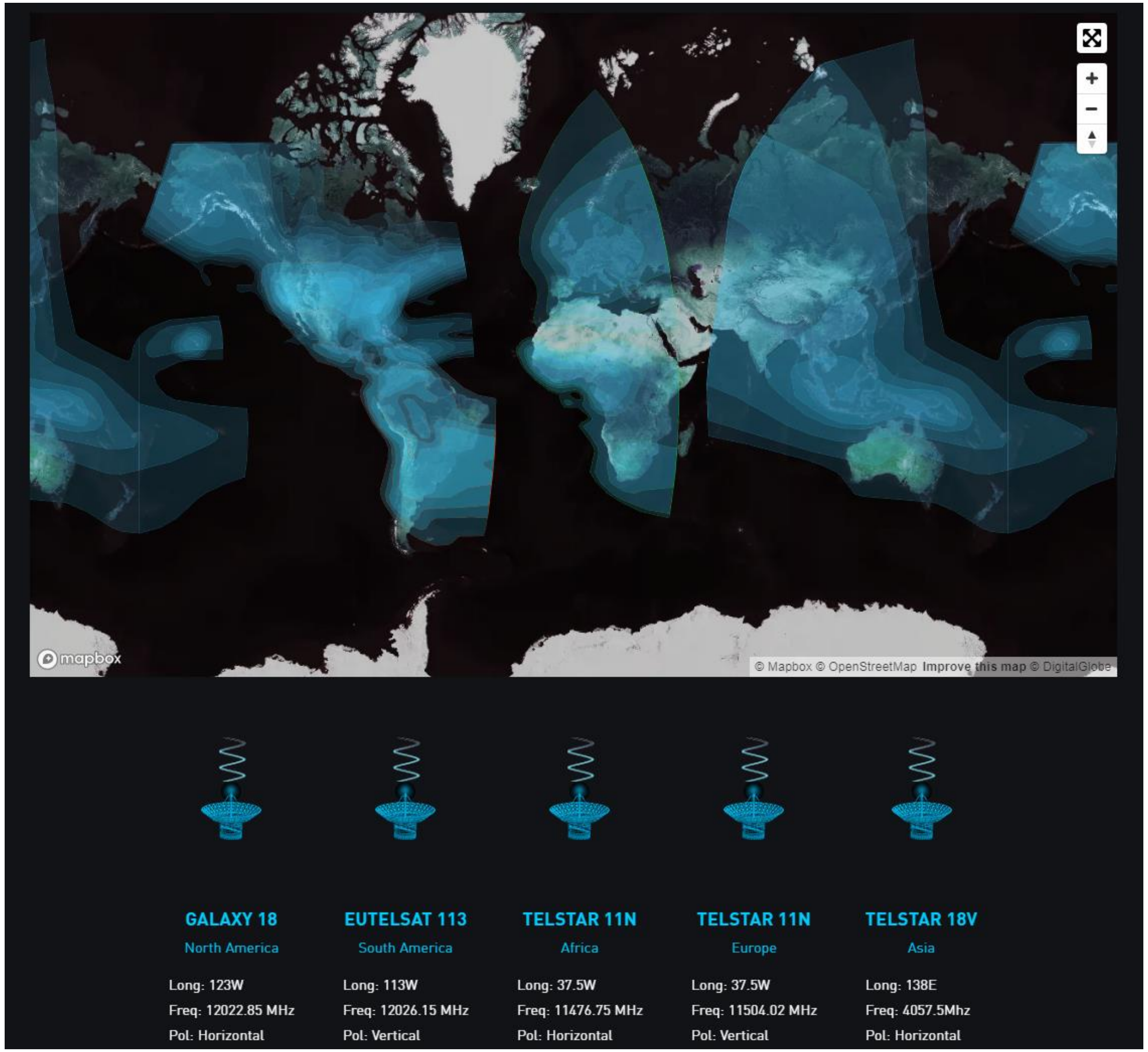
```
BB BB BB BB BB BB BB BB BB BB BB BB BB BB BB
AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA
BB BB BB BB BB BB BB BB BB BB BB BB BB BB BB
AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA
BB BB BB BB BB BB BB BB BB BB BB BB BB BB BB
AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA
BB BB BB BB BB BB BB BB BB BB BB BB BB BB BB
AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA
BB BB BB BB BB BB BB BB BB BB BB BB BB BB BB
AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA
BB BB BB BB BB BB BB BB BB BB BB BB BB BB BB
AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA
BB BB BB BB BB BB BB BB BB BB BB BB BB BB BB
AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA
BB BB BB BB BB BB BB BB BB BB BB BB BB BB BB
AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA
BB BB BB BB BB BB BB BB BB BB BB BB BB BB BB
AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA
BB BB BB BB BB BB BB BB BB BB BB BB BB BB BB
AA AA AA AA AA AA AA AA AA AA AA AA AA AA AA
BB BB BB BB BB BB BB BB BB BB BB BB BB BB BB
```

Modem B

Modem A sends data “A” to Modem B, and Modem B sends data “B” in response.

But the data received by Modem A is "C"!

BITCOIN-SATELLITE NETWORK

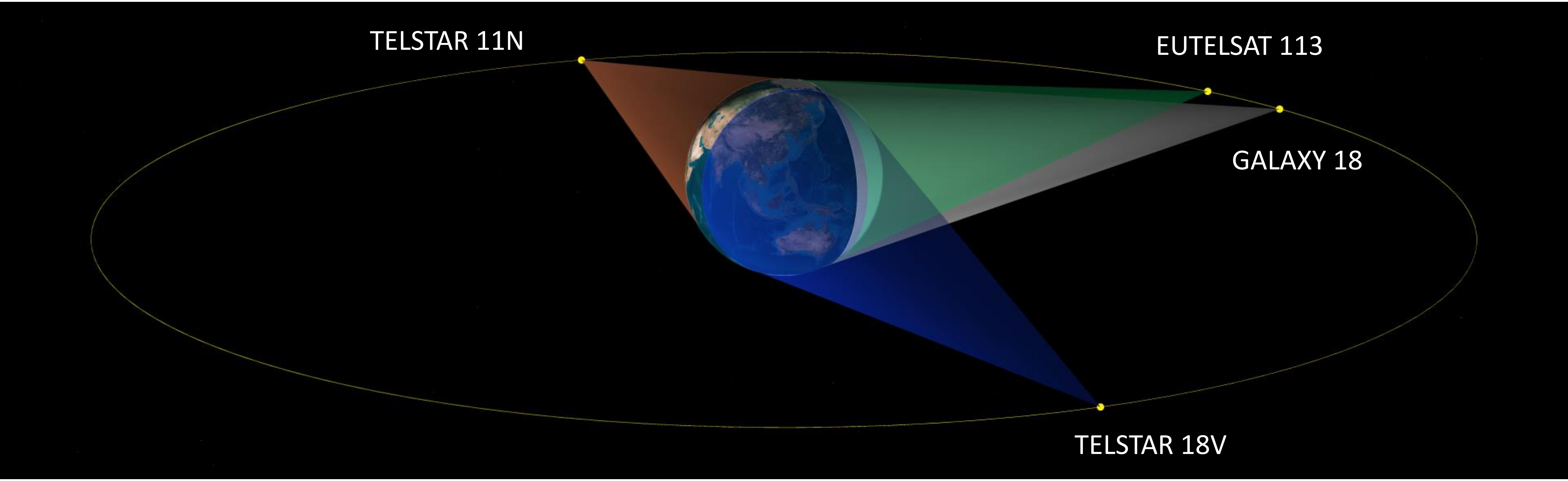


GALAXY 18	EUTELSAT 113	TELSTAR 11N	TELSTAR 11N	TELSTAR 18V
North America	South America	Africa	Europe	Asia
Long: 123W	Long: 113W	Long: 37.5W	Long: 37.5W	Long: 138E
Freq: 12022.85 MHz	Freq: 12026.15 MHz	Freq: 11476.75 MHz	Freq: 11504.02 MHz	Freq: 4057.5Mhz
Pol: Horizontal	Pol: Vertical	Pol: Horizontal	Pol: Vertical	Pol: Horizontal

Blockstream

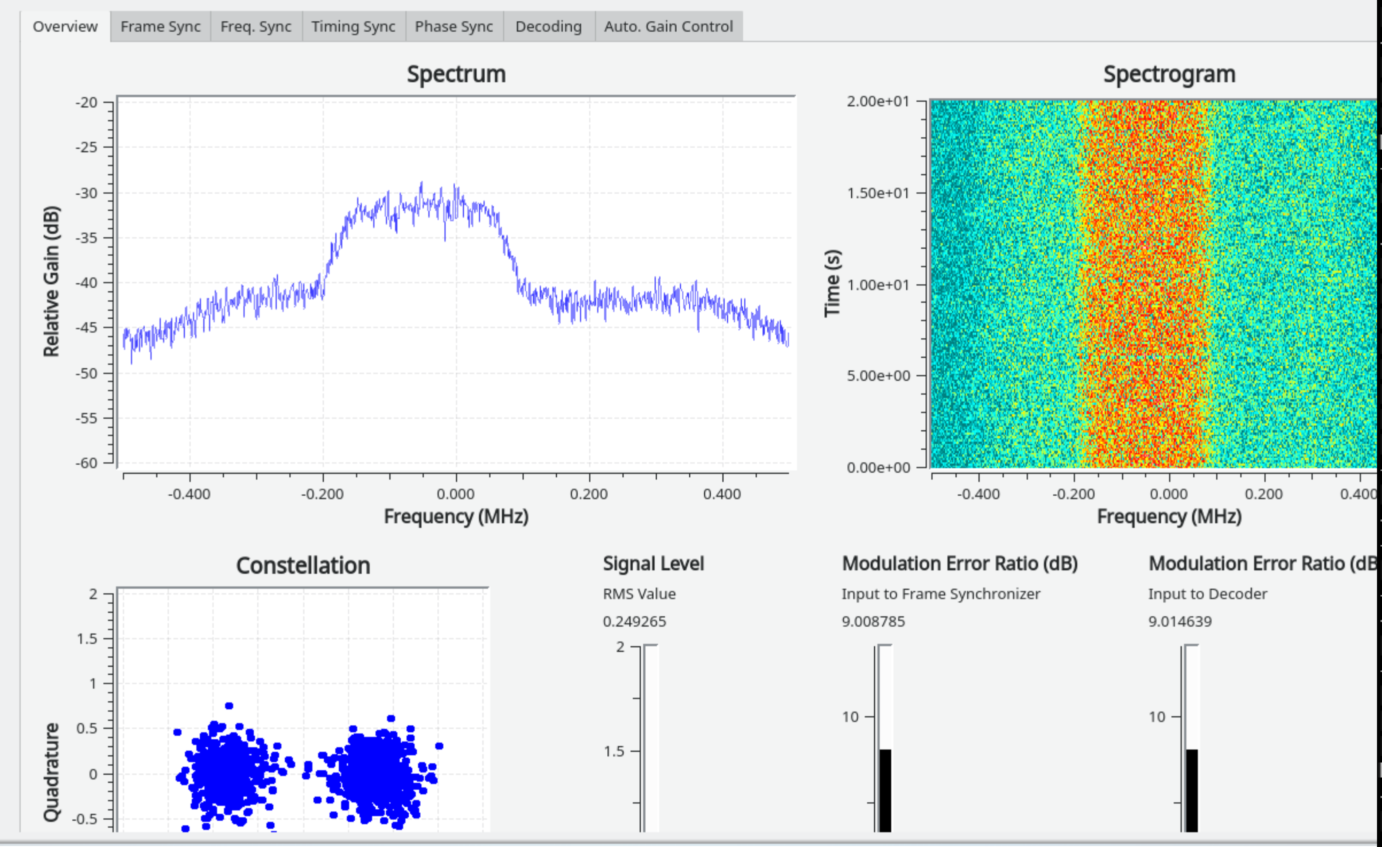
They transmit bitcoin transaction information via satellite networks to places where there is no network around the world.

SATELLITE SIMULATION



TELSTAR 18V
Downlink Freq:4057.5MHz
Uplink Freq = 4057.5MHz+2225MHz=6282.5MHz

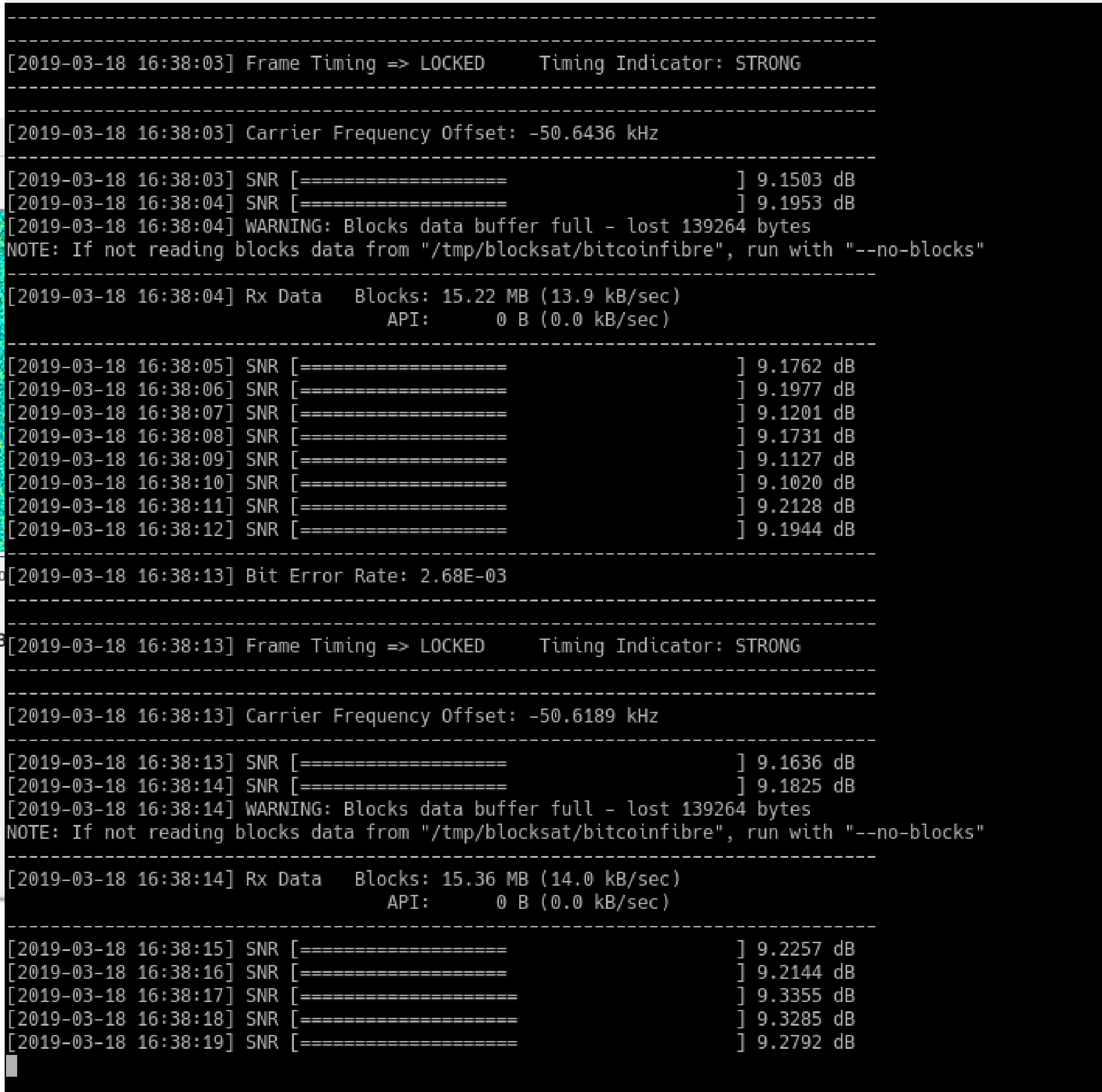
THE FIRST TIME IN THE ASIAN REGION TO SUCCESSFULLY RECEIVE BITCOIN DATA DISTRIBUTED BY BLOCKSTREAM



Signal Level
RMS Value
0.249265

Modulation Error Ratio (dB)
Input to Frame Synchronizer
9.008785

Modulation Error Ratio (dB)
Input to Decoder
9.014639



```
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
[2019-03-18 16:38:03] Frame Timing => LOCKED     Timing Indicator: STRONG
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
[2019-03-18 16:38:03] Carrier Frequency Offset: -50.6436 kHz
--------------------------------------------------------------------------------
[2019-03-18 16:38:03] SNR [===================                     ] 9.1503 dB
[2019-03-18 16:38:04] SNR [===================                     ] 9.1953 dB
[2019-03-18 16:38:04] WARNING: Blocks data buffer full - lost 139264 bytes
NOTE: If not reading blocks data from "/tmp/blocksat/bitcoinfibre", run with "--no-blocks"
--------------------------------------------------------------------------------
[2019-03-18 16:38:04] Rx Data   Blocks: 15.22 MB (13.9 kB/sec)
                                   API:      0 B (0.0 kB/sec)
--------------------------------------------------------------------------------
[2019-03-18 16:38:05] SNR [===================                     ] 9.1762 dB
[2019-03-18 16:38:06] SNR [===================                     ] 9.1977 dB
[2019-03-18 16:38:07] SNR [===================                     ] 9.1201 dB
[2019-03-18 16:38:08] SNR [===================                     ] 9.1731 dB
[2019-03-18 16:38:09] SNR [===================                     ] 9.1127 dB
[2019-03-18 16:38:10] SNR [===================                     ] 9.1020 dB
[2019-03-18 16:38:11] SNR [===================                     ] 9.2128 dB
[2019-03-18 16:38:12] SNR [===================                     ] 9.1944 dB
--------------------------------------------------------------------------------
[2019-03-18 16:38:13] Bit Error Rate: 2.68E-03
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
[2019-03-18 16:38:13] Frame Timing => LOCKED     Timing Indicator: STRONG
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
[2019-03-18 16:38:13] Carrier Frequency Offset: -50.6189 kHz
--------------------------------------------------------------------------------
[2019-03-18 16:38:13] SNR [===================                     ] 9.1636 dB
[2019-03-18 16:38:14] SNR [===================                     ] 9.1825 dB
[2019-03-18 16:38:14] WARNING: Blocks data buffer full - lost 139264 bytes
NOTE: If not reading blocks data from "/tmp/blocksat/bitcoinfibre", run with "--no-blocks"
--------------------------------------------------------------------------------
[2019-03-18 16:38:14] Rx Data   Blocks: 15.36 MB (14.0 kB/sec)
                                   API:      0 B (0.0 kB/sec)
--------------------------------------------------------------------------------
[2019-03-18 16:38:15] SNR [===================                     ] 9.2257 dB
[2019-03-18 16:38:16] SNR [===================                     ] 9.2144 dB
[2019-03-18 16:38:17] SNR [====================                    ] 9.3355 dB
[2019-03-18 16:38:18] SNR [====================                    ] 9.3285 dB
[2019-03-18 16:38:19] SNR [====================                    ] 9.2792 dB
```

Thanks

- 360 Technology home page: https://www.360.cn
- Twitter: Rasiel_J