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Wireless Signal Injection Attacks on VSAT Satellite Modems

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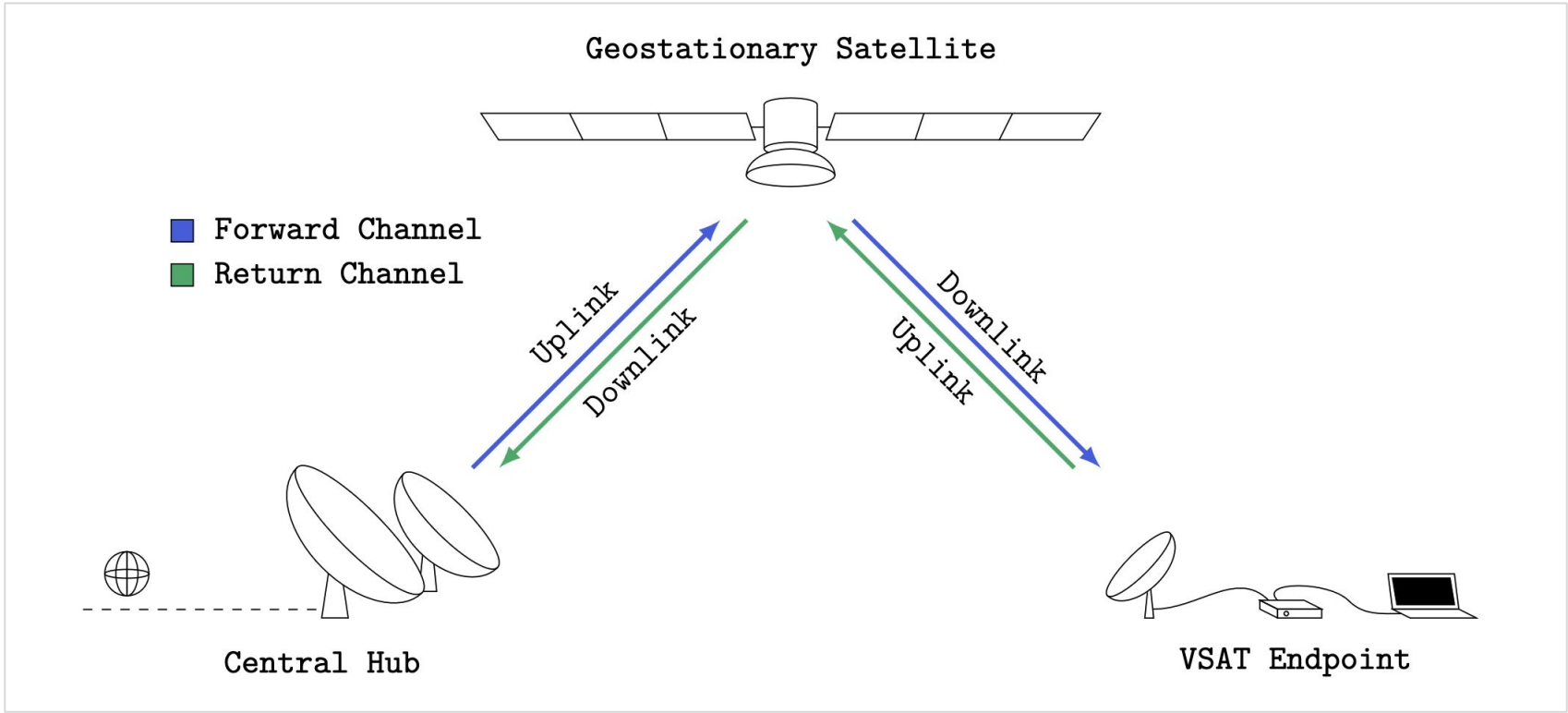
Martin Strohmeier, Vincent Lenders

USENIX Security ‘24, Philadelphia

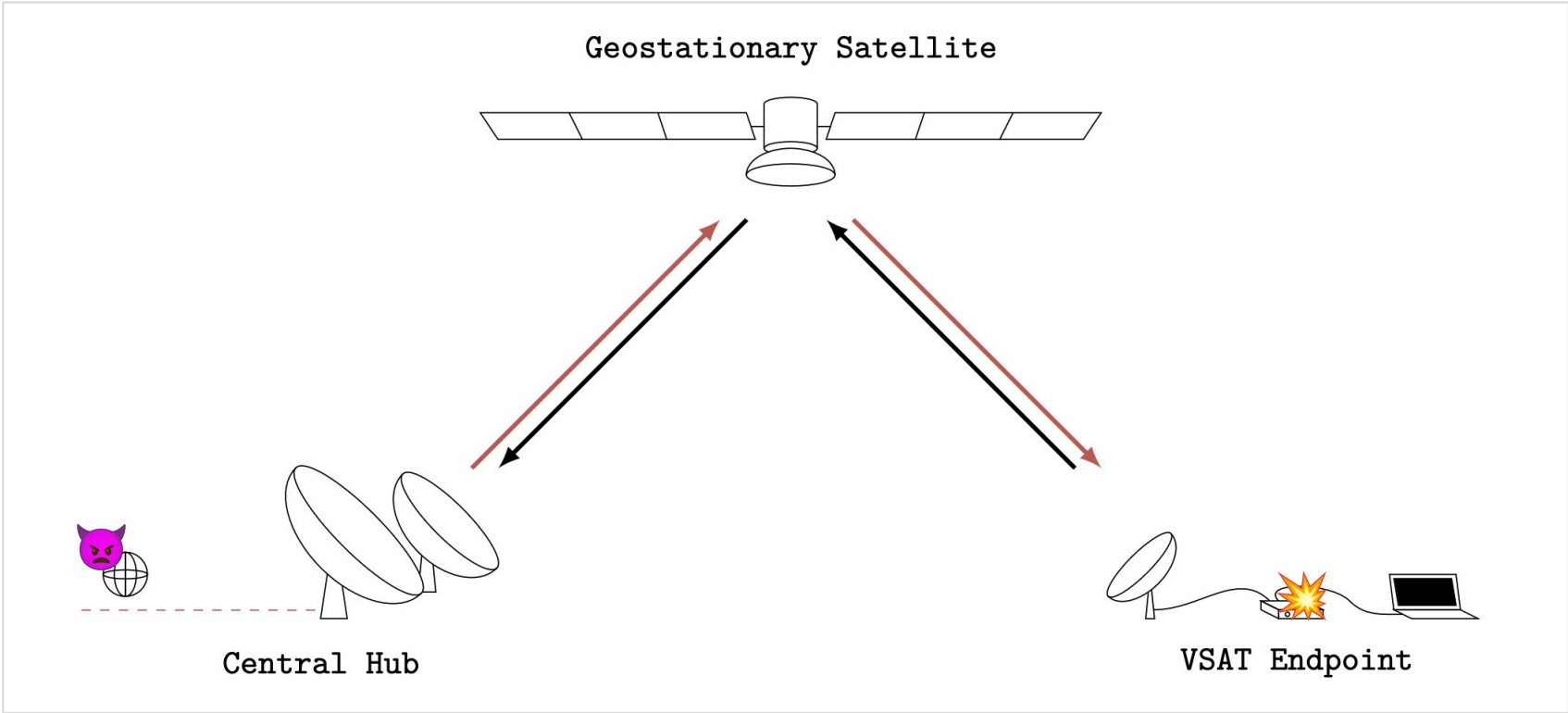
Ben Wicks / Unsplash

Background
VSAT Satellite Communication Systems

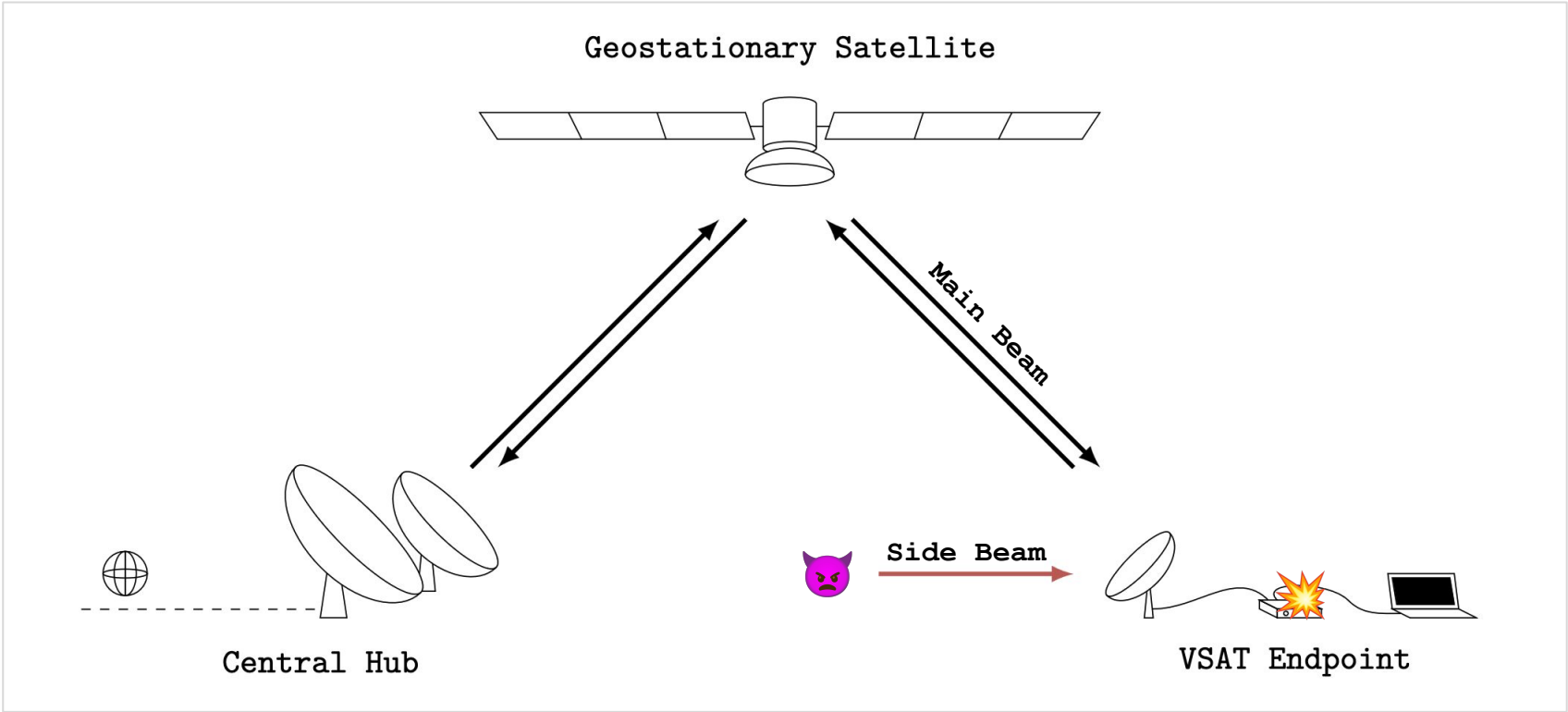



Businessweek
The Satellite Hack Everyone Is Finally Talking About
As Putin began his invasion of Ukraine, a network used throughout Europe—and by the Ukrainian military—faced an unprecedented cyberattack that doubled as an industrywide wake-up call.
By Katrina Manson
Illustrations by Jordan Speer
1 March 2023 at 00:01 GMT+1
https://www.bloomberg.com/features/2023-russia-viasat-hack-ukraine/

Attack Scenarios
Attacking Central Hubs



Attack Scenarios
Attacking VSAT Endpoints



Research Question

How are VSAT satellite modems susceptible to side beam signal injection attacks?

Attacker Model

Knowledge 📖

- Knowledge of the modem's communication stack and applications

Transmission capabilities 📡

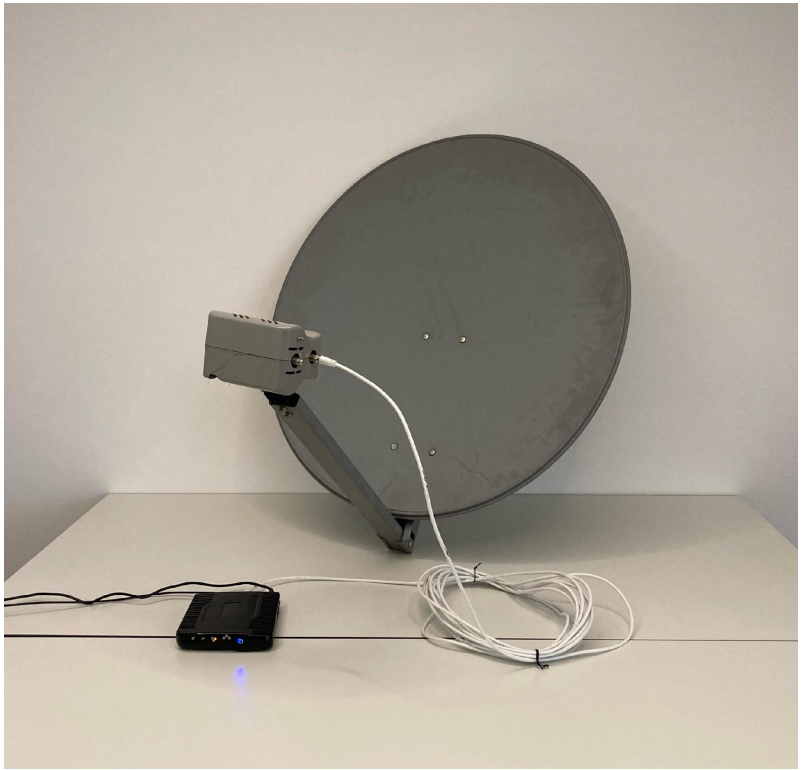
- SDR-based transmission on the forward channel
- Ability to upconvert to satellite frequencies (Ku- and Ka-band)

Line-of-sight 🔭

- **No physical access to modem**
- Line-of-sight to the modem, but outside of the main beam

https://pxhere.com/en/photo/1290044

Case Study
Newtec MDM2200



Centers of Excellence in the U.S., Belgium & Singapore serve the unique needs of each region

5000 hubs deployed supporting over half million modems

#1 Ranking in maritime market – trusted by **8 of the 9 leading service providers** – connecting seafarers and vessels worldwide amongst cruise, oil and gas, commercial shipping and fishing industries

#1 Ranking in aero with 44% market share – linking thousands of passengers, cockpit and ground support crew across **3,000+ commercial planes and business jets**

#1 Ranking in media and broadcast market – enhancing live broadcast capabilities for more than 5 years, enabling more than **3 billion people to watch TV every day**

Leading the digital transformation of the ground segment through strategic partnership with Microsoft Azure and the DIFI consortium

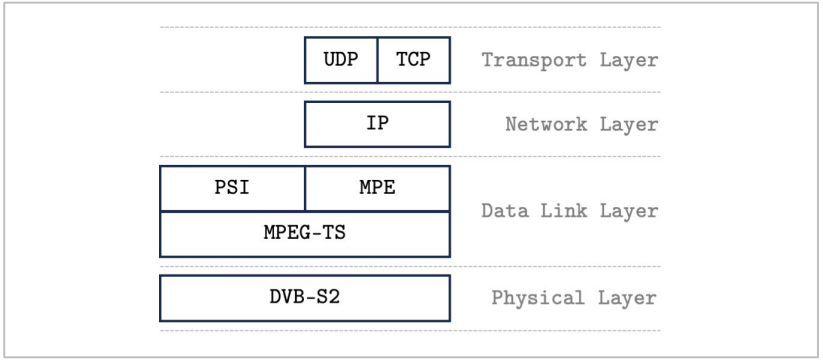
Leading industry collaboration and unified standardization to enable the integration of **5G over satellite**

Global leader in government and defense – **#1 ranking in U.S. DoD VSAT** and relied on by 21 of 28 EU nations and 19 of 29 NATO member states

https://www.idirect.net/wp-content/uploads/2020/01/2022-Corporate-Factsheet-US.pdf

Case Study
DVB-RCS / Sat3Play

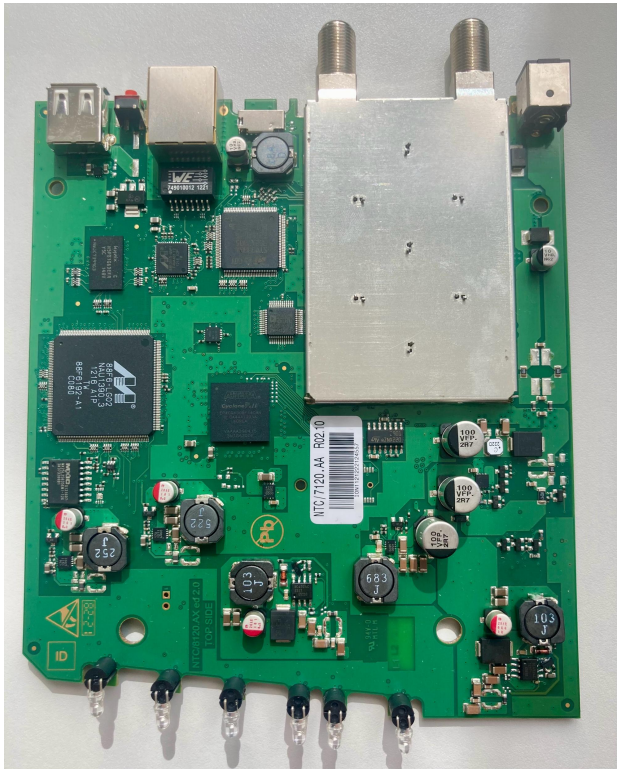
DVB-RCS provides a **standardized framework for satellite communication**.

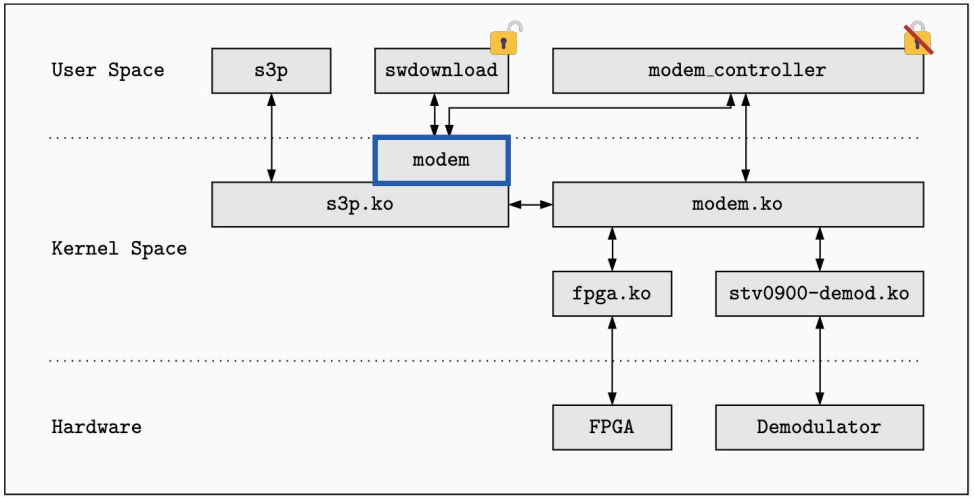


S3P is Newtec's **proprietary implementation of DVB-RCS**.

- It deviates from DVB-RCS in some respects.
- **Encryption is optional** and not enforced.

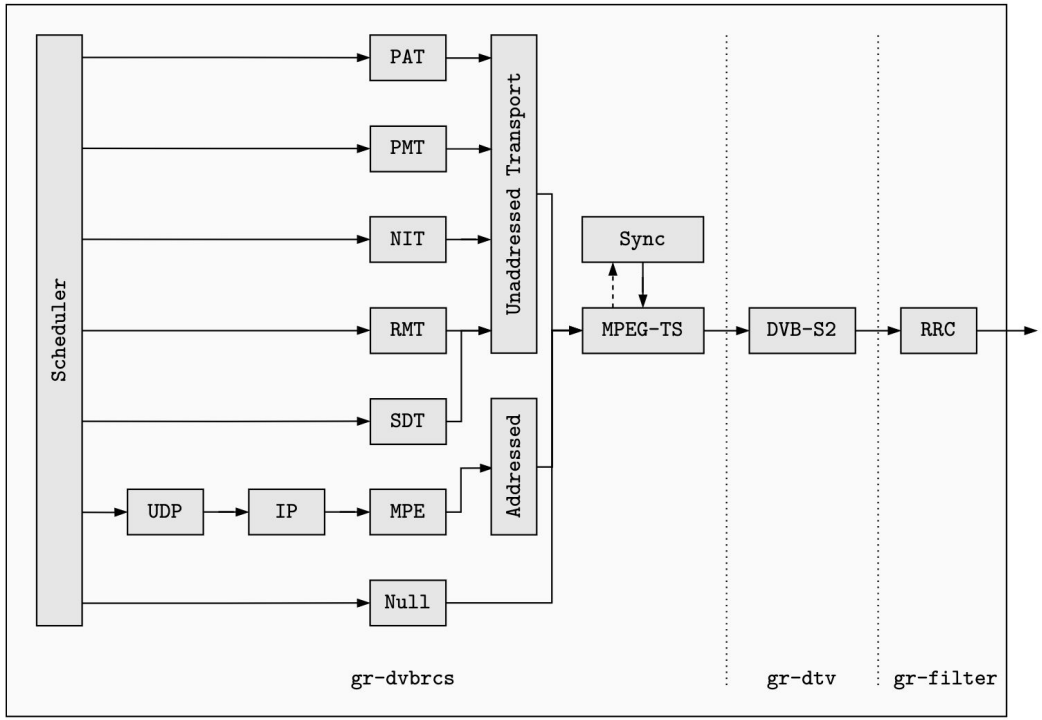
Case Study
Newtec MDM2200





- The modem abstracts the signal processing behind a **network interface**, which accepts all incoming traffic.
- There is **no coordinated approach to security**. Management applications apply unencrypted and unauthenticated instructions.

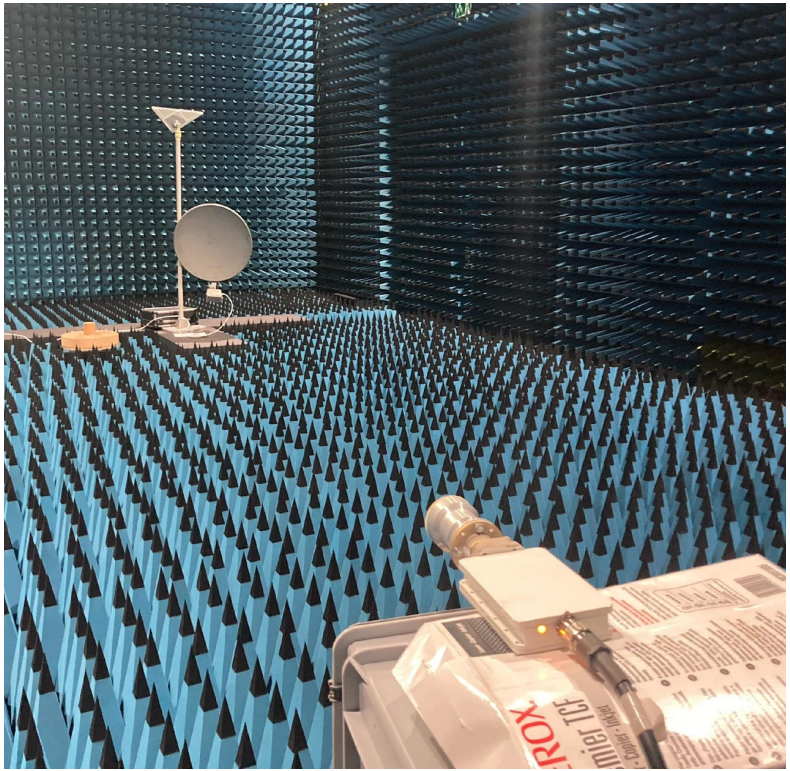
Implementation
Transmitter

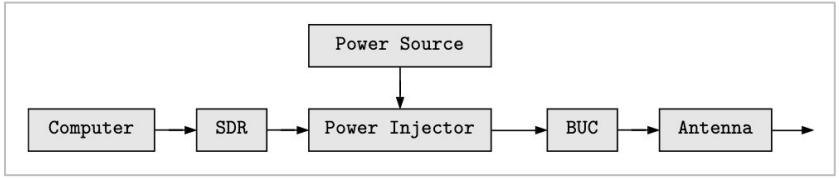


- GNU Radio based implementation of only the **forward channel**.

✓ Our implementation allows us to **inject arbitrary IP packets** into the modem's network stack.

Implementation
Hardware Setup





- Software-defined Radio:
  Ettus Research USRP B200
- Power Injector:
  UMT-TV BUC-Ku002-10.6 v2.0
- Block Upconverter:
  UMT-TV DC Injector IDCI with IP Ctrl
- Antenna:
  UMT-TV Offset Feed

~ $2000

Attack 1
Connection Reset

- We emit a **jamming signal** consisting of random noise at the same frequency as the forward channel.

✓ Because the modem is no longer able to receive the synchronization packets, the **modem restarts the channel initialization process**.

Attack 2
Malicious Firmware Update

- We emit a signal, containing a packet indicating that an update is available, followed by malicious firmware update packets.
- Both packet types are **neither authenticated nor encrypted**.

```
Jan 1 00:00:38 S3P user.info swdownload[396]: All data received
Jan 1 00:00:38 S3P user.info swdownload[396]: All packets received
Jan 1 00:00:38 S3P user.info swdownload[396]: SW download finished
Jan 1 00:00:38 S3P user.err  swdownload[396]: CRC on the header was not correct!
Jan 1 00:00:38 S3P user.err  swdownload[396]: - Calculated=1972200246, expected=0n
Jan 1 00:00:38 S3P user.info swdownload[396]: CRC not correct!
```

✓ The modem confirms the **successful firmware reception**.

✓ Allows an attacker to **overwrite the firmware**.

Attack 3
Remote Code Execution

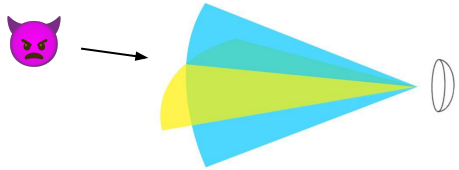
- We emit a signal that contains an **exploit of a buffer overflow vulnerability**.

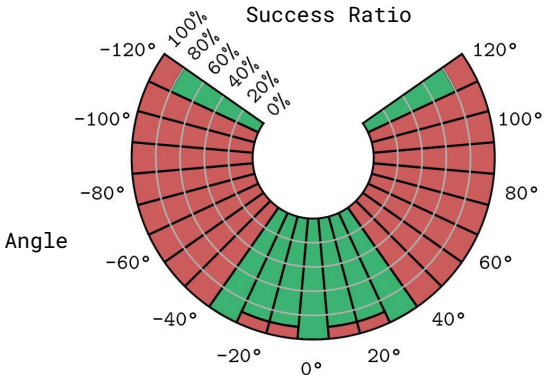
✓ We were able to execute commands with visibly verifiable results, for example by **turning on an LED**.

✓ We were able to open a **reverse shell to a host in the LAN**.

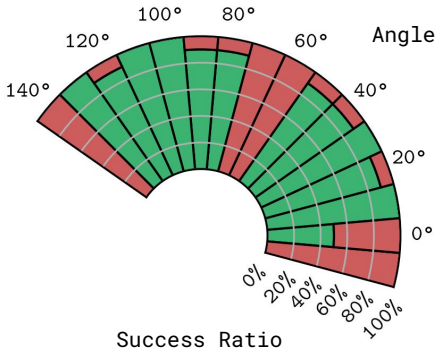
Evaluation
Sidelobe Injection

TX power: 9.5dBm
Environment: Anechoic





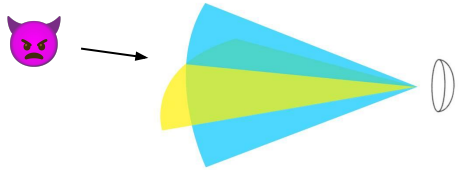
Horizontal plane
(yellow)

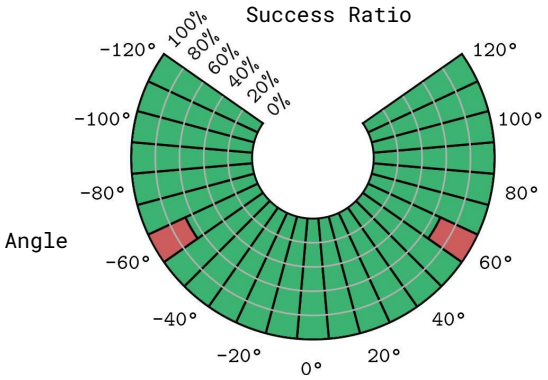


Vertical plane
(blue)

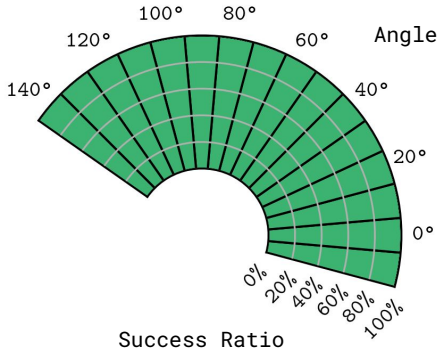
Evaluation
Sidelobe Injection

TX power: 9.5dBm
Environment: Multipath





Horizontal plane
(yellow)



Vertical plane
(blue)

Conclusion
Real-World Impact

- Attacks are expected to be effective on other modems utilizing **Sat3Play**.
- We believe the results of this study can be adapted to devices from other vendors based on **DVB-RCS** (e.g., Viasat, Hughes, Advantech, and Satlink).
- These solutions are estimated to hold a **10-20%** market share out of millions of deployed VSAT terminals.

Conclusion
Research Contributions

- We **reverse engineered the communication** stack of the Newtec MDM2200 modem.
- We implemented an **SDR attacker** with a budget of **$2000**.
- We demonstrated **three wireless attacks**:
  - Resetting the connection
  - Injecting malicious firmware updates
  - Obtaining a remote admin shell
- We found that signal injection attacks can be **successful from angles other than directly in front of the antenna**.
- We discussed the real-world impact and **potential mitigations**.

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https://www.usenix.org/conference/usenixsecurity24/presentation/bisping