

# Building an Autonomous World-Wide HF Band Wireless Network

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## Introduction - HERMES

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- HERMES was born from the struggle to provide telecommunication access to indigenous and riverside communities in the Amazon rainforest.
- For decades many communities in Amazon, Central Africa, and other places without telecom infrastructure relied on analog SSB HF radios for long range voice communication.
- While HF telecom was once the most advanced long range wireless communication technology, nowadays its civil use is restricted to enthusiasts and isolated communities, and is technologically stuck in the 60's. HERMES aims to push forward civil HF telecom state-of-the-art.
- HERMES provides a digital telecommunication solution for HF which allows the deployment of regional and worldwide autonomous networks without any pre-existing telecom infrastructure.

# Introduction - The HF Band

- Defined by ITU as the electromagnetic spectrum between 3 MHz and 30 MHz
- The HF band allows very wide coverage thanks to the Earth's ionosphere reflective properties for the HF band (MF too)
- The propagation type of a signal that reflects or refracts in the ionosphere is called skywave
- HF is the most resilient telecommunication media and is very hard to track a transmission

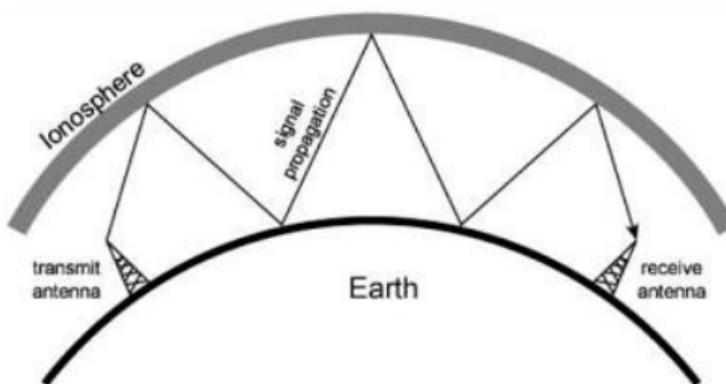
Band Name	Symbols	Frequency range
Very low frequency	VLF	3 to 30 kHz
Low frequency	LF	30 to 300 kHz
Medium frequency	MF	300 to 3000 kHz
High frequency	HF	3 to 30 MHz
Very high frequency	VHF	30 to 300 MHz
Ultra high frequency	UHF	300 to 3000 MHz
Super high frequency	SHF	3 to 30 GHz
Extremely high frequency	EHF	30 to 300 GHz
Terahertz (ITU, 2015b)	THz	300 to 3000 GHz

Source: ITU (2012), Radio Regulations Article 2

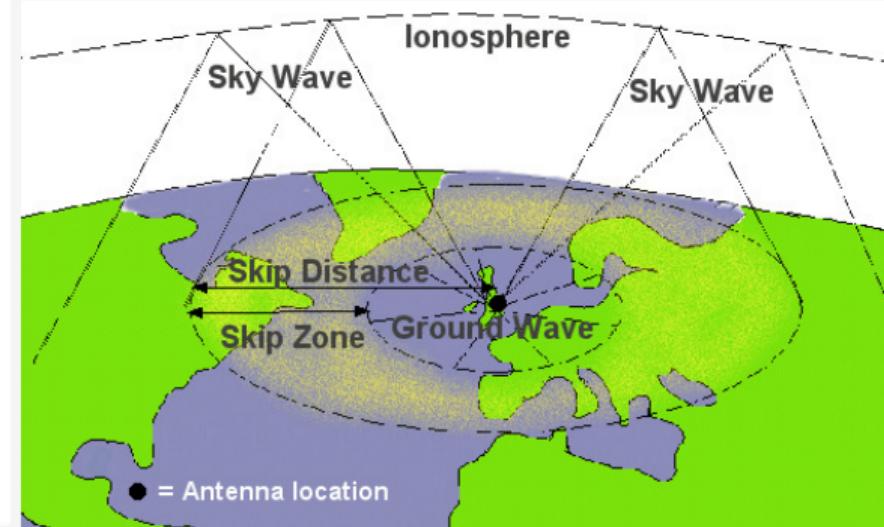
# Introduction - Skywave propagation

- The Ionosphere is located in the upper atmosphere, from 80 up 1000 km in altitude
- Skywave can be used for relatively short distances, up to hundreds of kilometers, and long distances communication, to any point on Earth

## Sky Wave Propagation

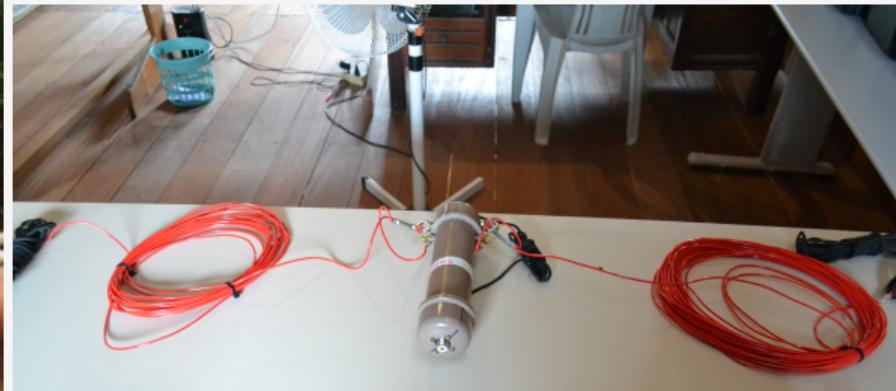


(b) Sky-wave propagation (2 to 30 MHz)



## Introduction - HF Antenna

- Frequencies: between 3 MHz and 10 MHz typical for regional coverage
- Antennas (Example): dipole or folded dipole typical, in horizontal or inverted V layout



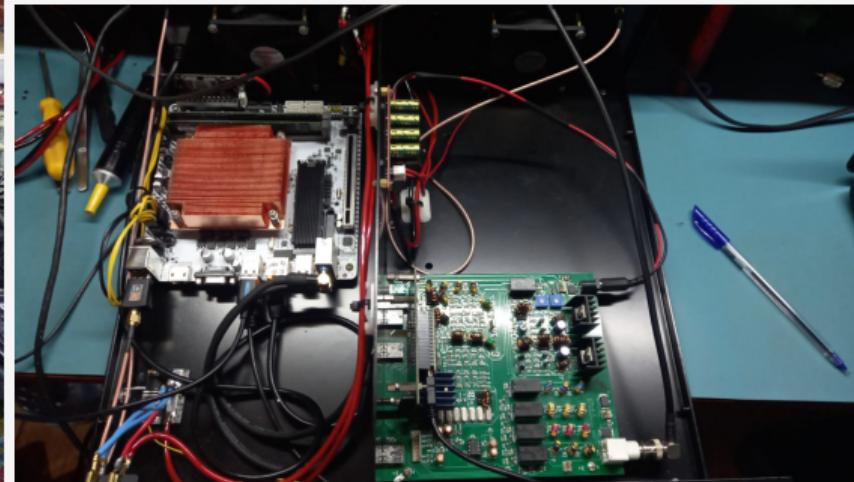
## HERMES History

- Fonias Juruá (2015): Stock HF SSB transceiver connected to a box with radio interface, Raspberry Pi and touch screen. Modem used is HamDRM (DRM narrowband).



# HERMES History

- HERMES v1 (2018-2020): Rhizomatica's developed integrated Digital HF solution. One box includes the HF transceiver (a customized µBitx) connected to a computer. Modem used is Ardop or VARA, transport system is UUCP.



# HERMES History

- HERMES v1.1 (2021-2022): HF Transceiver with integrated GPS for accurate time and PLL frequency synthesis and redesigned lambda bridge. Improved email compression. Focus on email service and the use of DeltaChat at communities.



# HERMES History

- HERMES v1.x (2019-2023): Workshops and deployments in Amazon region.
- HERMES v2 (2023-): Workshops and ongoing first deployment in Central Africa.



# HERMES History

- HERMES v2 (2023-): Adopted another open source wideband HF transceiver: the sBitx. Much reduced size and has native voice support (mic+ptt+speaker). Development ongoing of the Mercury modem for high-speed wideband capability.



# HF Telecommunication

## HF Network Stack

- Channelization: “old” analog-world framework (3 kHz bw), plus support to wider channels, channel aggregation and smart channel allocation
- Wideband HF transceiver
- Layer 1 (modem): all waveform, modes and bandwidths.
- Layer 2 (datalink): framing, Automatic Repeat reQuest (ARQ), Media Access Control (MAC)
- UUCP, IP, other network / transport layer
- Store-and-forward services (eg. email, sensors data)
- Voice (mobile telephony) and messaging services
- A tutorial on frequency adaptive communication systems in the HF bands, ITU-R, 2022  
<https://www.itu.int/pub/R-HDB-64-2022>

# Real-world network example

- In the Amazon rainforest region, Pará state, northern Brazil



# HERMES system features

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- Station equipment (sBitx) contains a HF transceiver and a Raspberry Pi 4
- UUCP based telecommunication over HF
- Users access HERMES services over WiFi (AP exposed by the equipment)
- BBS-like direct “station-to-station” messages (audio and image supported!)
- Email is the main service. Emails are highly compressed before going over the air
- Emails are synchronized to a “gateway” node over HF, which routes emails among HF nodes or the Internet

## User interface - WEB Frontend

<https://github.com/Rhizomatica/hermes-gui>

- Provides users Web access to configurations
- User management for both Web UI and email
- Multi-language: en, es, pt, fr
- Message system (BBS like)
- System logs, UUCP queue management
- UI for voice communication with easy frequency and mode (USB, LSB) selection and volume adjustment

# User interface - WEB Frontend

<p>9.300,00 kHz LSB</p>	 <p>Messages</p>	 <p>E-mail</p>	 <p>Aide</p>
 <p>Configuration de la radio</p>	 <p>Gestion des utilisateurs</p>	 <p>Configuration des messages</p>	 <p>Liste de transmission</p>
 <p>Information sur les stations</p>	 <p>Gestionnaire Wi-Fi et ethernet</p>	 <p>Journal détaillé</p>	<p>Thème sombre</p> <p>Déconnexion </p>



# User interface - WEB Frontend

## Configuration de la radio

Déconnecté	Fréquence données 9.300,00 kHz LSB	SWR 1.3
Puissance 22.3 W	Mode d'opération RX	Numéro de série 0
Fréquence données radio : 9.300,00kHz <input type="text" value="9300"/> <a href="#">changer la fréquence</a>	Seuil d'activation de la protection <input type="text" value="25"/> <a href="#">changer la limite</a>	
Mode USB <input checked="" type="radio"/> LSB	PTT (OFF) <input type="radio"/>	
protection (OFF)	<a href="#">réinitialisation</a>	<a href="#">réinitialisation aux paramètres par défaut</a>
<a href="#">redémarrer</a>	<a href="#">SOS emergency</a>	

# User interface - WEB Frontend

The screenshot shows a web-based user interface for managing messages. At the top left is the HERMES logo and the URL 'estacao4.hermes.radio'. On the right side, there are status indicators for 'USB 1.085,50 kHz digital' and a menu icon. Below the header, a breadcrumb navigation shows '/home /messages'. The main content area has a title 'Message public ?' with two buttons: 'nouveau' (new message) and 'messages envoyés' (sent messages). A search bar with a magnifying glass icon is positioned below the buttons. The main list displays five messages, each with a delete icon (trash can) and a timestamp. The messages are:

- PU2UIT-4, 30/11/2023, 04:26 PM  
Nouveau message fichier
- PU2UIT-4, 01/06/2023, 08:24 PM  
test message
- PU2UIT-4, 25/05/2023, 08:19 PM  
Mensagem com senha
- PU2UIT-4, 25/05/2023, 08:15 PM  
Mensagem com senha
- PU2UIT-4, 25/05/2023, 08:13 PM

A power button icon is located at the bottom right of the list.

# User interface - WEB Frontend

 HERMES  
estacao4.hermes.radio

USB 1.085,50 kHz  
digital

Nouveau message fichier



MONSANTO

 download.jpeg

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Origine : PU2UIT-4  
Destination : estacao4  
Envoyé à : 30/11/2023, 04:26 PM



# User interface - WEB Frontend

The screenshot shows a web-based user interface for the HERMES system. At the top left is the logo 'HERMES' with the URL 'estacao4.hermes.radio'. At the top right are status indicators for 'USB 1.085,50 kHz digital' and a menu icon. Below the header, a breadcrumb navigation shows '/home /email'. The main content area is titled 'E-mail' with a help icon. It contains two links: 'Webmail' with a blue and white icon and 'Deltachat' with a blue and white icon. A horizontal line separates this from the download instructions. Below the line, the text reads 'Pour télécharger Deltachat cliquez sur un des liens ci-dessous :'. Underneath are five download links: 'Android' (orange), 'Windows' (orange), 'Ubuntu/Debian' (orange), 'Mac OSX' (orange), and 'Ubuntu/Debian' (orange). A note at the bottom states: '\*Note: On Iphone and ipad you will need to download the app from the App Store in a place with internet.' Below this is a link 'Configurer deltachat' with a help icon. In the bottom right corner, there is a power button icon.

HERMES  
estacao4.hermes.radio

USB 1.085,50 kHz  
digital

< /home /email

## E-mail ②

Webmail

Deltachat

Pour télécharger Deltachat cliquez sur un des liens ci-dessous :

[Android](#)

[Windows](#)

[Ubuntu/Debian](#)

[Mac OSX](#)

\*Note: On Iphone and ipad you will need to download the app from the App Store in a place with internet.

Configurer deltachat ②

# User interface - Analog Voice Telephony

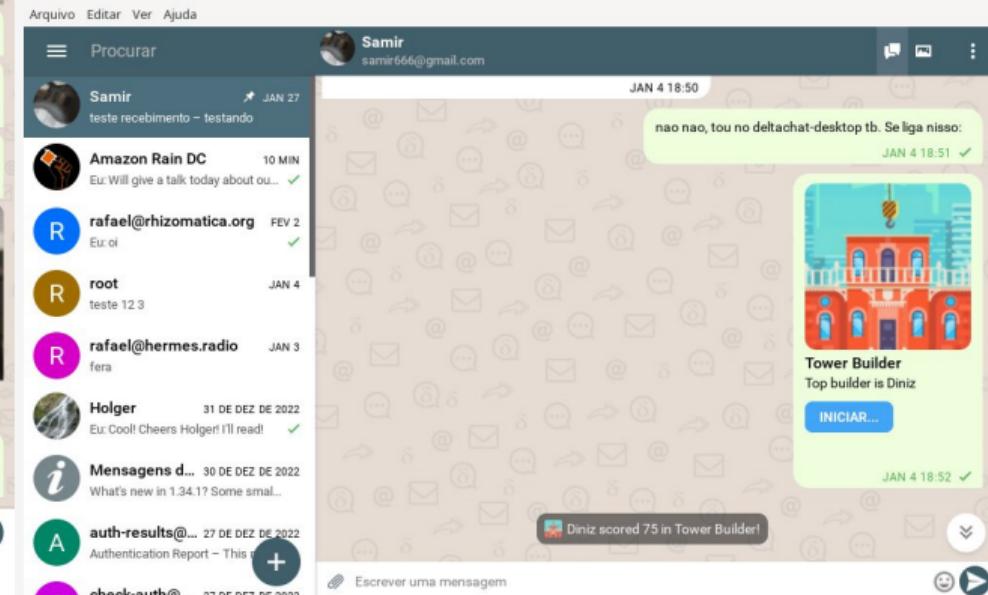
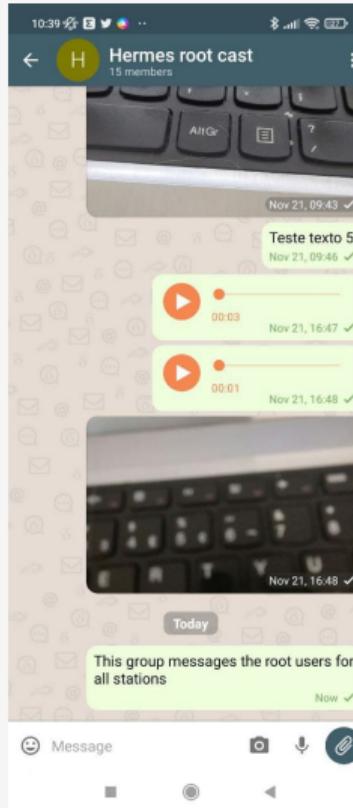
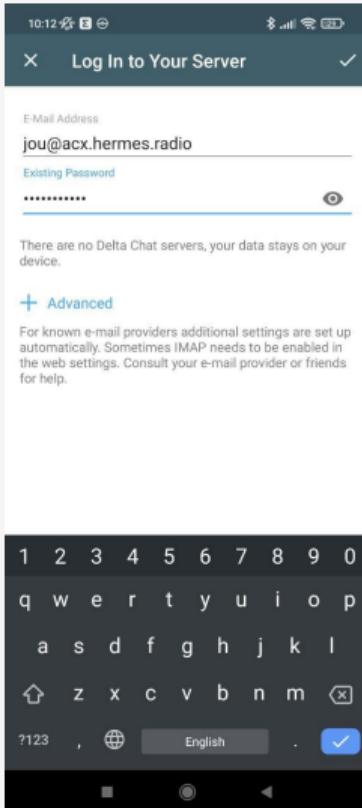


# E-mail

## E-mail stack

- E-mail software (Postfix, Dovecot) run in HERMES radio
- E-mail compression using uuxcomp called directly from postfix (!crmail), many headers stripped, xz compression
- Specific transcoding for audio (LPCNet) and image (VVC) attachments at uuxcomp
- One station (called “gateway”) routes the emails between HF nodes and a main email server with public IP address (for routing over the Internet)
- DeltaChat is the recommended email client

# DeltaChat



# REST Backend

<https://github.com/Rhizomatica/hermes-api>

- Radio API: set/get frequency, mode, power levels, volume, swr protection trigger, etc
- User API: user management for web admin access and e-mail accounts (same login)
- Messages API: direct message between hosts (just a uucp copy of a packaged message)
- System API: set/get system status / configuration
- UUCP API: provides a way to list and delete UUCP jobs, and start a connection (uucico)
- Gateway API: provides scheduling facilities and station/frequency table

## Good ol' UUCP

### Taylor's UUCP goes over the air

- UUCPD bridges UUCP to HF modem through pipes and shared memory
- The UUCP nodename is the station callsign
- Protocol 'y' is used, and long timeouts are set

/etc/uucp/port:

port HFP

type pipe

command /usr/bin/uuport -c \Z

# HERMES-specific network stack components (hermes-net repo)

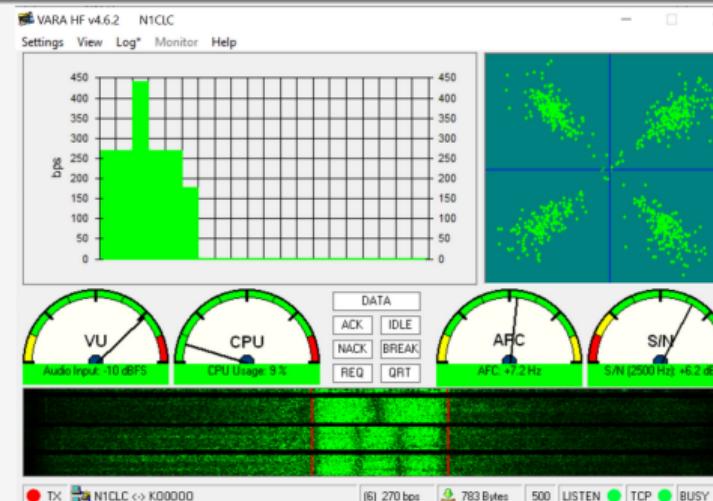
<https://github.com/Rhizomatica/hermes-net>

- `trx_v1-{firmware,userland}`: HERMES v1 transceiver firmware and radio control tools
- `trx_v2-userland`: HERMES v2 control and DSP software for the sBitx radio
- `uucpd`: UUCP daemon and tools (bridges UUCP and the HF modem)
- `uuxcomp`: uux wrapper which compresses an e-mail before enqueueing it, and `crmail` to decompress
- `system_scripts`: image and audio compression scripts, email and uucp management, gateway “caller”, etc
- `system_services`: init scripts and udev rules

# SDR Modem

Currently using VARA HF

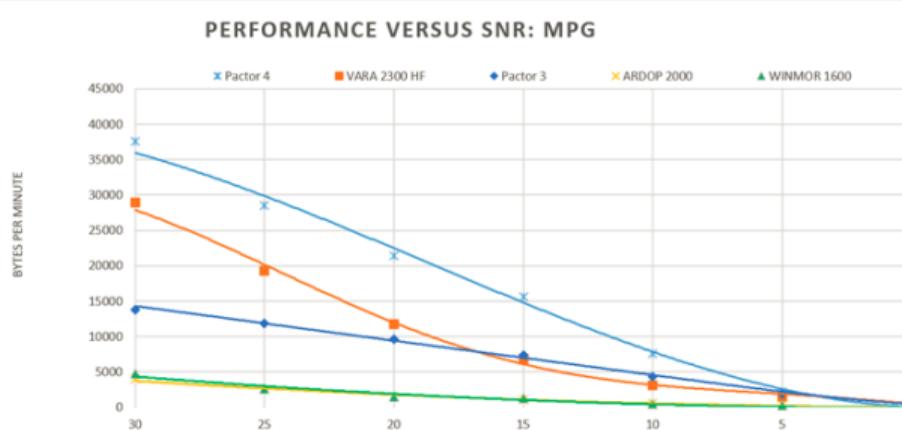
- 2300 Hz BW, ARQ, Adaptive Modulation
- Modes range from 16 bps up to 5 kbps
- Proprietary Visual Basic 6 application (runs well on Hangover-Wine)



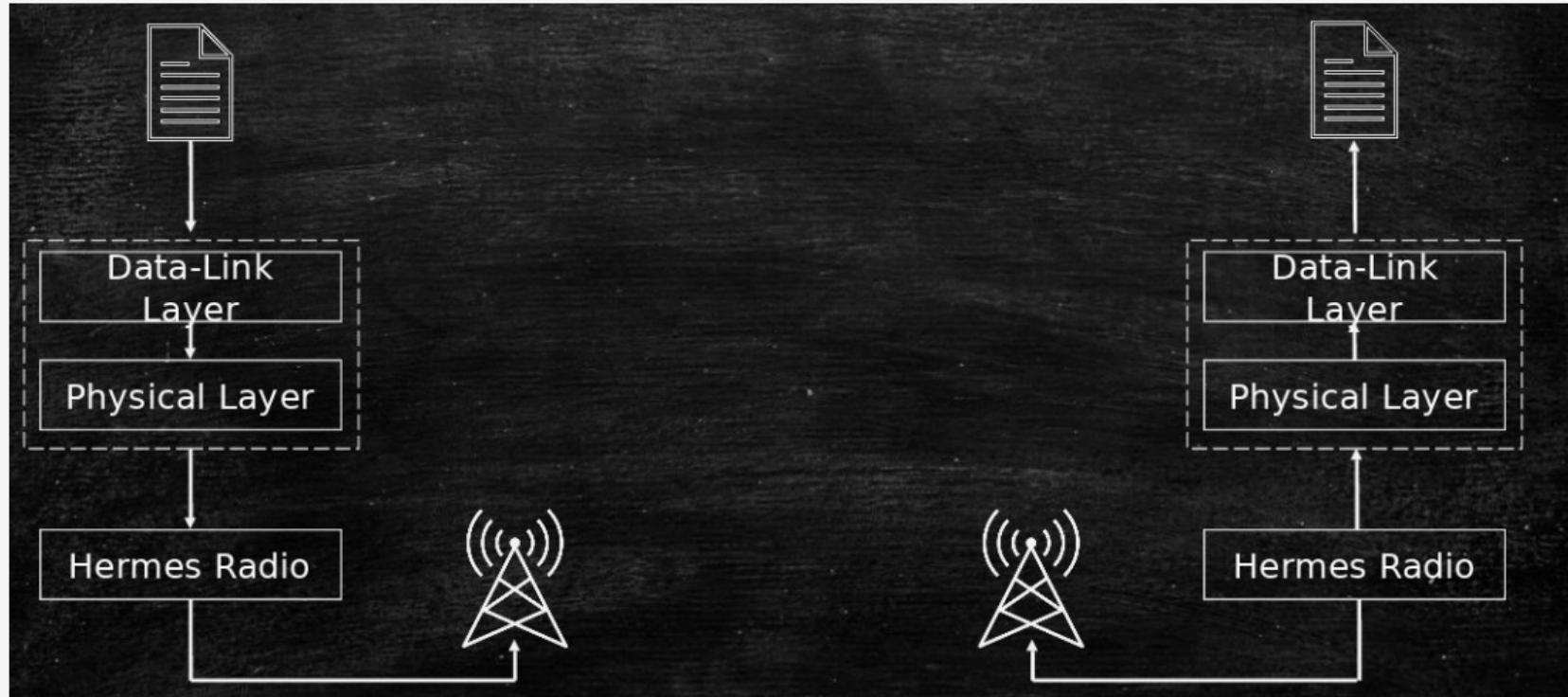
# SDR Modem

Mercury <https://github.com/Rhizomatica/mercury>

- Open source configurable software-defined modem (layers 1 and 2)
- Modulation BPSK, QPSK, 8QAM, 16QAM, 32QAM and 64QAM
- LDPC code rate 2/16, 8/16 and 14/16
- ARQ and adaptive modulation to address different propagation conditions



# Mercury



# Mercury Data-Link Layer



Configurable Data Block size

to avoid fast TX/RX switch



Gear-Shift

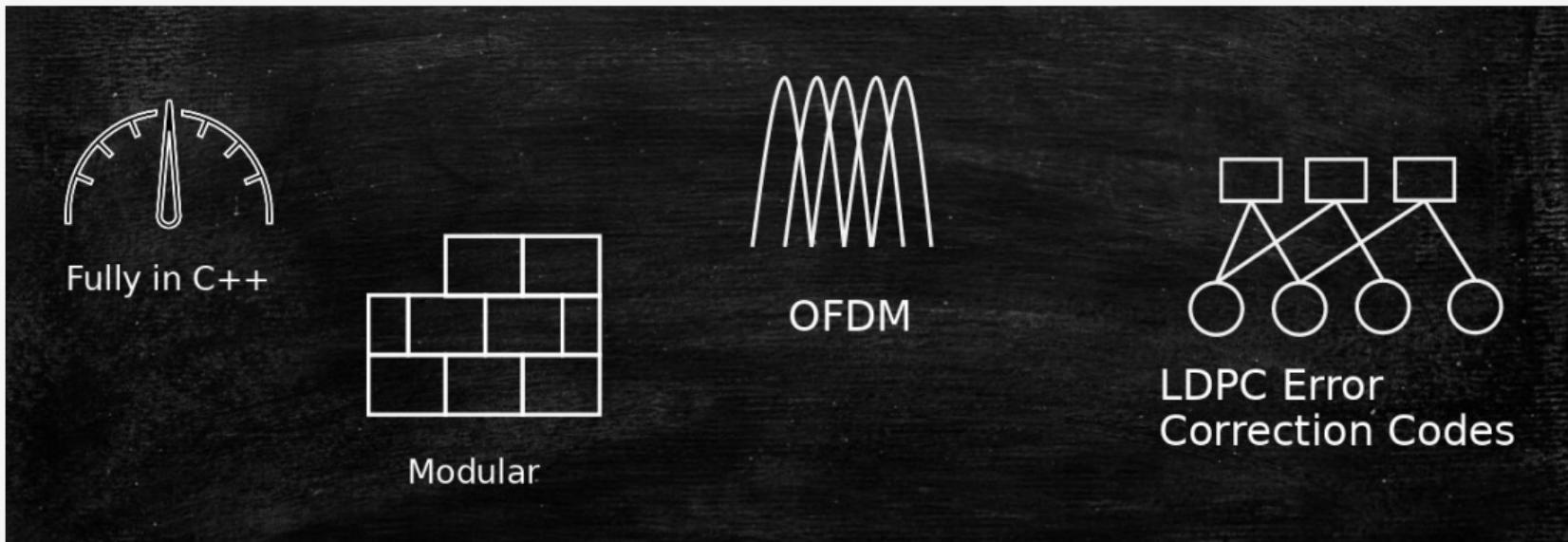


Automatic repeat requests  
(ARQ)



TCP/IP Interface

# Mercury Physical Layer



## Other characteristics

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- Robust (and stealth!) operation with 0db or less of SNR for signal reception
- Integration to SMS and other messaging services  
(<https://github.com/Rhizomatica/hermes-messaging/>)
- Sensors data acquisition and transmission - binary data using paq8px compression  
(<https://github.com/Rhizomatica/hermes-sensors/>)
- Support for large scale and affordable deployments

## Steps for the realization of the WWWAN

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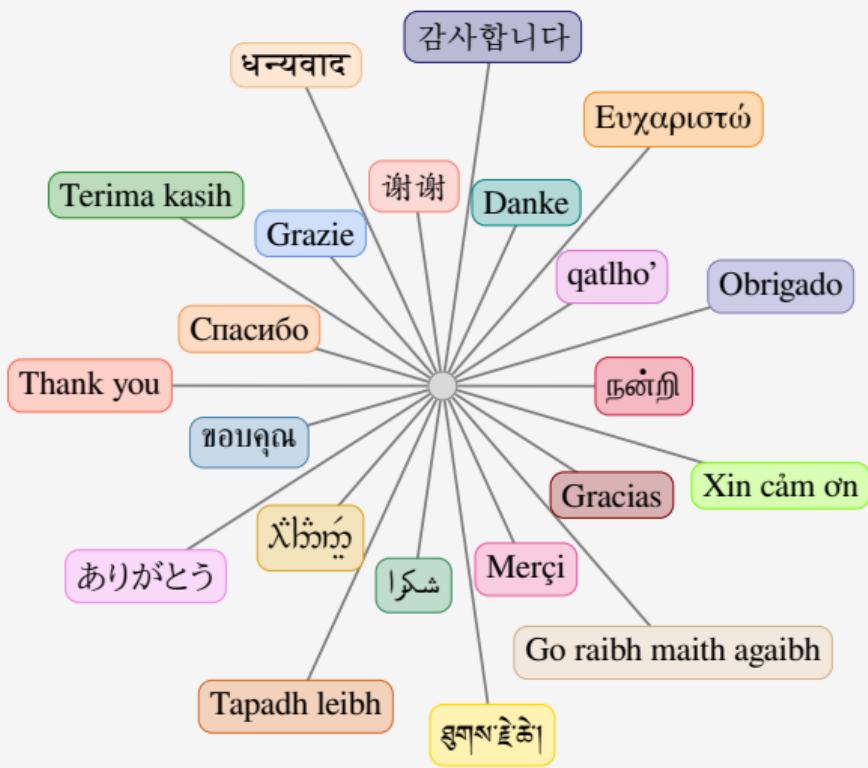
- Antenna miniaturization (nano tubes, micro strips?)
- Develop more advanced ML-based audio and image codecs
- NNCP instead of UUCP for improved security?
- Reticulum?
- Multiple users capability MAC
- Adaptive bandwidth and channels selection
- Support for real-time messaging
- Digital Mobile Telephony for HF
- DRM reception
- DRM broadcast

# Let's Build a Global Autonomous World-Wide Area Network?



## What you can do in today's conditions





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# Questions?