Long-range Telecommunication in the HF band

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HERMES
HIGH-FREQUENCY EMERGENCY AND
RURAL MULTIMEDIA EXCHANGE SYSTEM

Introduction - HERMES

- 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

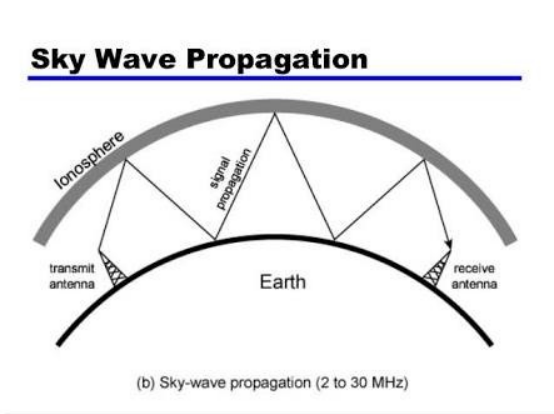
- Defined by ITU as the electromagnetic spectrum between 3 MHz and 30 MHz
- The HF band allows very wide coverage thanks to the Earth's ionosphere reflective properties for the HF band (MF too)
- The propagation type of a signal that reflects or refracts in the ionosphere is called skywave
- HF is the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

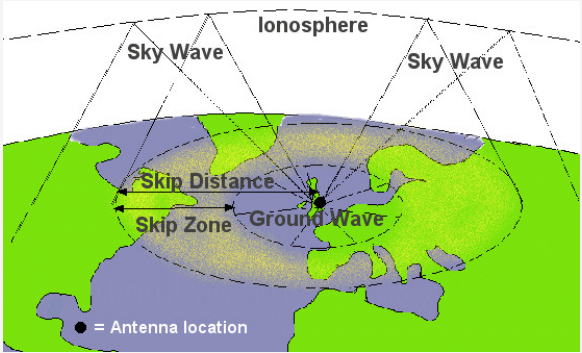
Band Name	Symbols	Frequency range
Very low frequency	VLF	3 to 30 kHz
Low frequency	LF	30 to 300 kHz
Medium frequency	MF	300 to 3000 kHz
High frequency	HF	3 to 30 MHz
Very high frequency	VHF	30 to 300 MHz
Ultra high frequency	UHF	300 to 3000 MHz
Super high frequency	SHF	3 to 30 GHz
Extremely high frequency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

Source: ITU (2012), Radio Regulations Article 2

Introduction - Skywave propagation

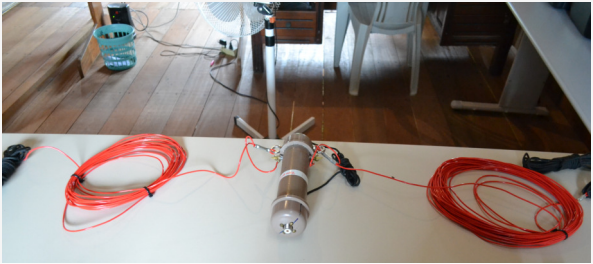
- The Ionosphere is located in the upper atmosphere, from 80 up 1000 km in altitude
- Skywave can be used for relativelly short distances, up to hundreds of kilometers, and long distances communication, to any point on Earth





Introduction - HF Antenna

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

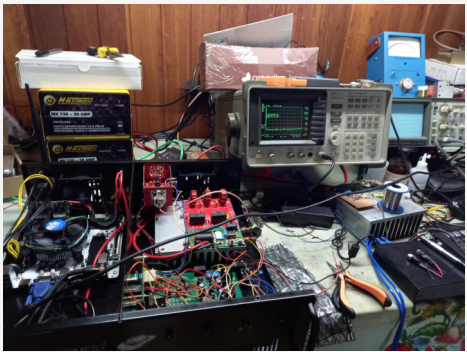


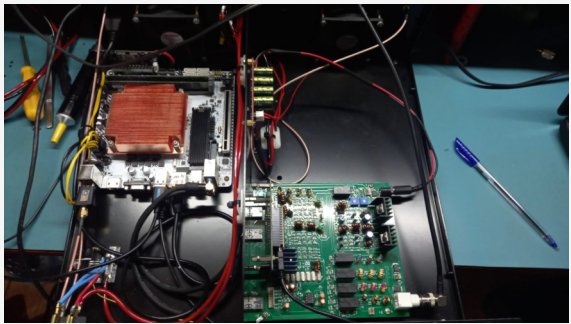
HERMES History

- Fonias Juruá (2015): Stock HF SSB transceiver connected to a box with radio interface, Rasperry 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 syntesis 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.

Real-world network example

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

HERMES system features

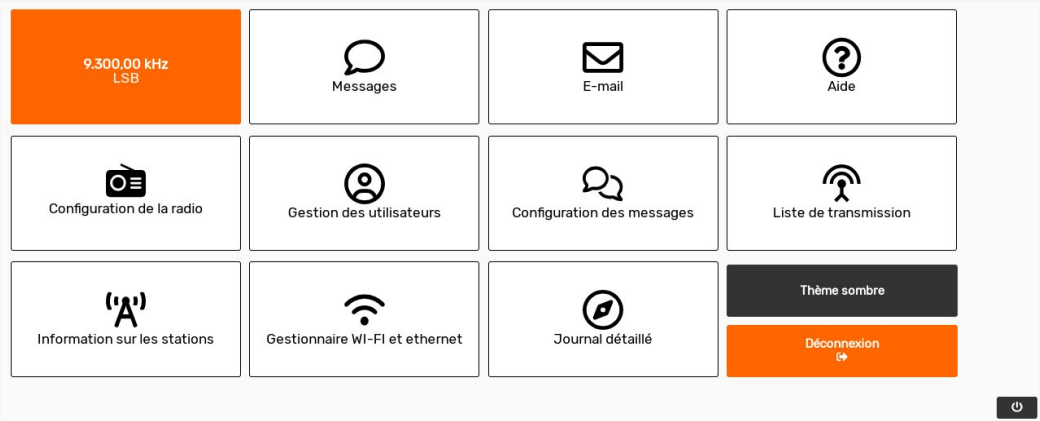
- Station equipment (sBitx) contains a HF transceiver and a Raspberry Pi 4
- UUCP based telecommunication over HF
- Users access HERMES services over WiFi (AP exposed by the equipment)
- BBS like direct “station-to-station” messages (audio and image too!)
- Email is the main service. Emails are highly 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



User interface - WEB Frontend

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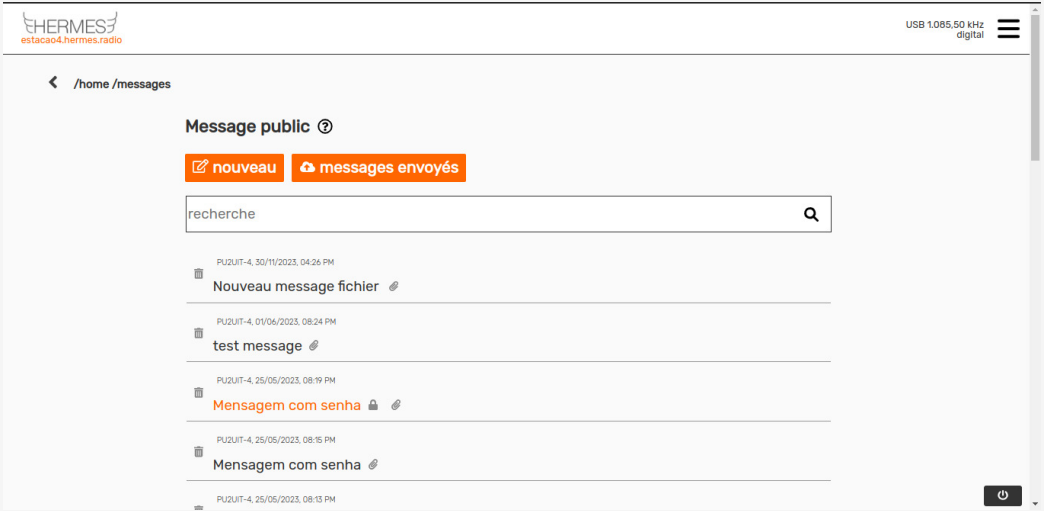
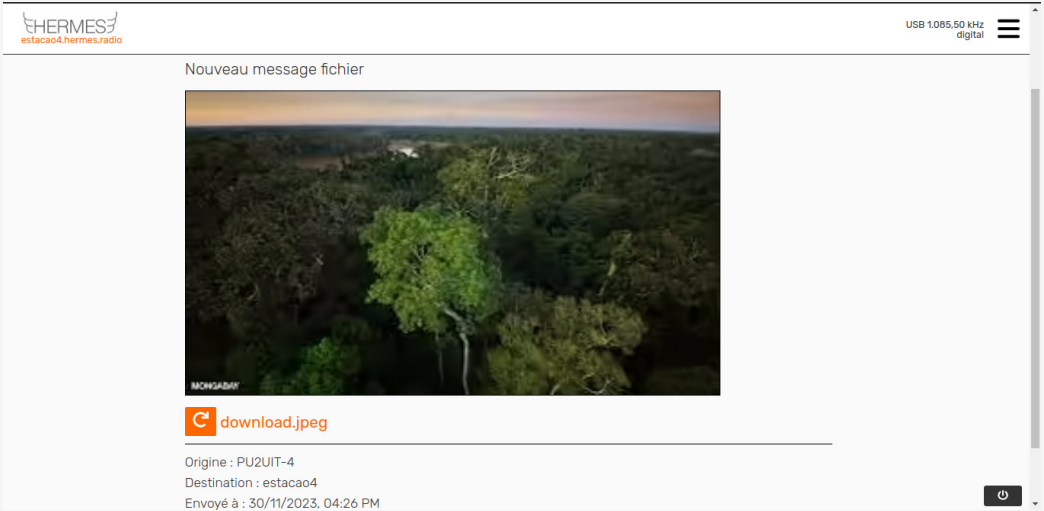
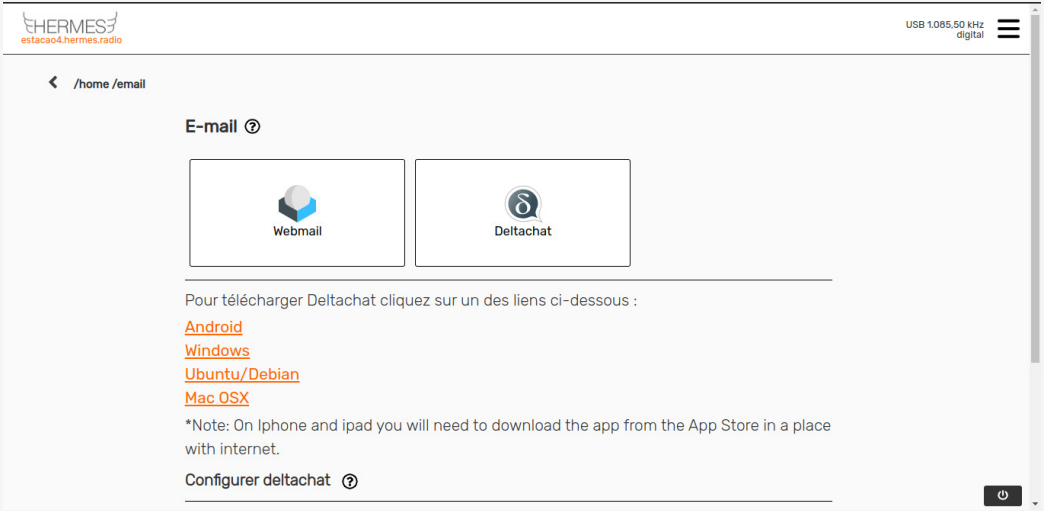


User interface - WEB Frontend



User interface - WEB Frontend



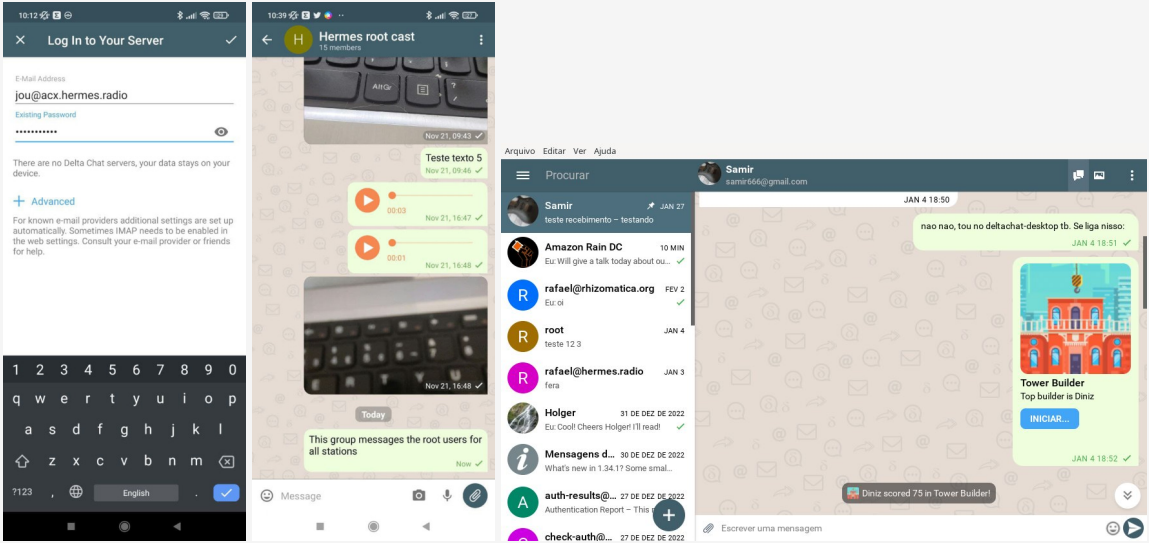
User interface - Analog Voice Telephony

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


Log In to Your Server
E-Mail Address
jou@acx.hermes.radio
Existing Password
There are no Delta Chat servers, your data stays on your device.
Advanced
For known e-mail providers additional settings are set up automatically. Sometimes IMAP needs to be enabled in the web settings. Consult your e-mail provider or friends for help.
Hermes root cast
15 members
Teste texto 5
This group messages the root users for all stations
Message
Arquivo Editar Ver Ajuda
Procurar
Samir
samir666@gmail.com
Amazon Rain DC
rafael@rhizomatica.org
root
rafael@hermes.radio
Holger
Mensagens d...
auth-results@...
check-auth@...
nao nao, tou no deltachat-desktop tb. Se liga nisso:
Tower Builder
Top builder is Diniz
INICIAR...
Diniz scored 75 in Tower Builder!
Escrever uma mensagem

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 facitities 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)

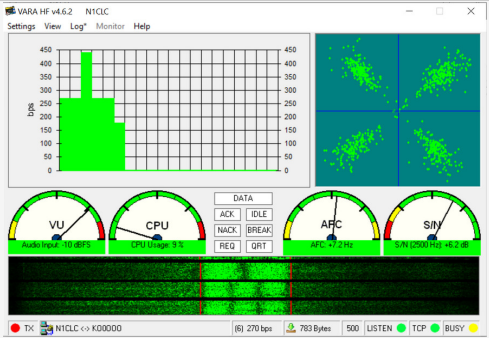
https://github.com/Rhizomatica/hermes-net

- 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 enqueuing 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

(software-defined) Modem

Currently using VARA HF

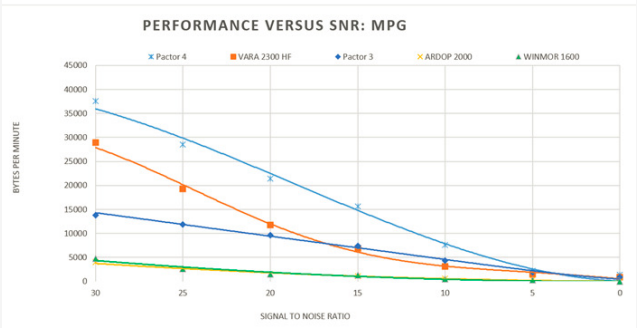
- 2300 Hz BW, ARQ, Adaptive Modulation
- Modes range from 16 bps up to 5 kbps
- Proprietary Visual Basic 6 application (runs well on Hangover-Wine)



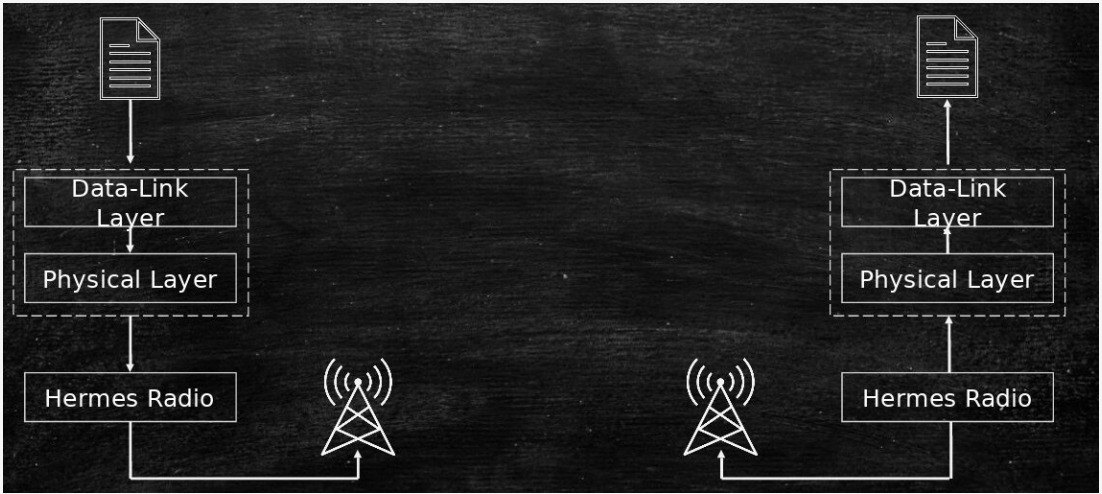
In Development - Mercury

https://github.com/Rhizomatica/mercury

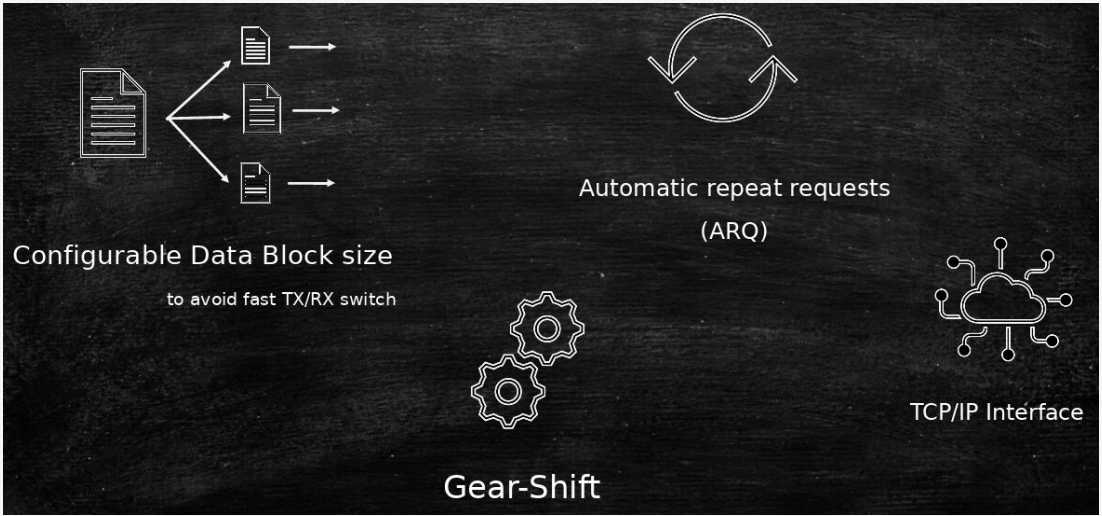
- Open source configurable software-defined modem (layers 0 and 1)
- Modulation BPSK, QPSK, 8QAM, 16QAM, 32QAM and 64QAM
- LDPC code rate 2/16, 8/16 and 14/16



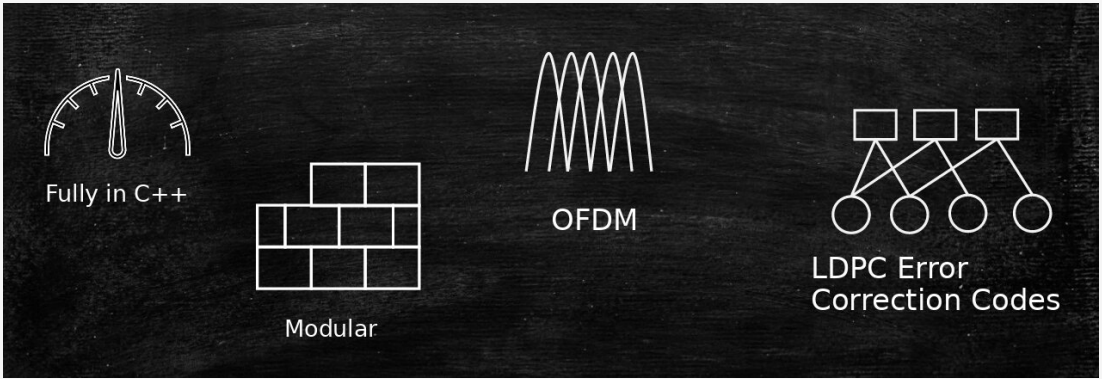
Mercury


Data-Link Layer
Physical Layer
Hermes Radio
Data-Link Layer
Physical Layer
Hermes Radio

Mercury Data-Link Layer



Mercury Physical Layer



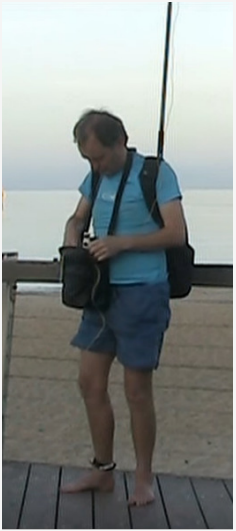
Current work

- Substitute VARA by Mercury - HERMES will be 100% Free Software!
- 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/)
- Supporting large scale deployment in Central Africa

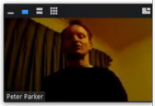
Possible future works

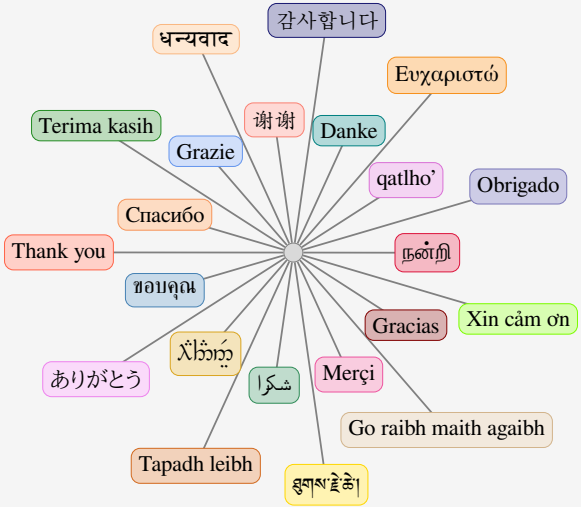
- Develop more advanced ML-based audio and image codecs
- NNCP instead of UUCP for improved security
- Multiple users capability (beyond P2P) MAC
- Adaptive bandwidth and channels selection
- Support real-time messaging
- Digital Telephony
- DRM reception
- DRM broadcast

HF Mobile Telephony



What you can do in today's conditions





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Questions?