Why Digital?

A survey of communication technology

Chris Petersen, K9EQ

Agenda

- Digital and FM: The good, the bad, and the ugly
- Something for nothing? The stuff that matters
- Popular modes
- What do Ham’s need?
- Dstar vs Fusion

FM vs Digital

Inexpensive & simple	Complexity
Variable & noisy	Consistent
Single “channel”	Multiple “channels”
Community	Isolation
Old and stagnant	Enabling

Digital Parameters

Modulation: OOK, ASK, FSK, GMSK, C4FM

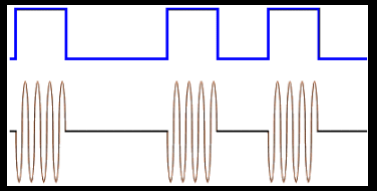
Bandwidth: Modulation index

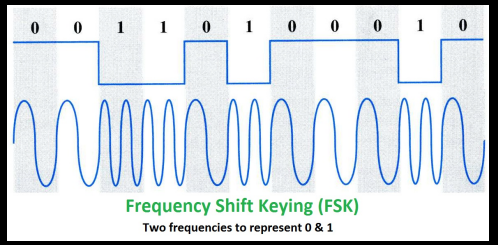
Bit rate: Voice, data, FEC

Encoding/compression (GSM, AMBE, MP3)

Modulation

OOK: On Off Keying



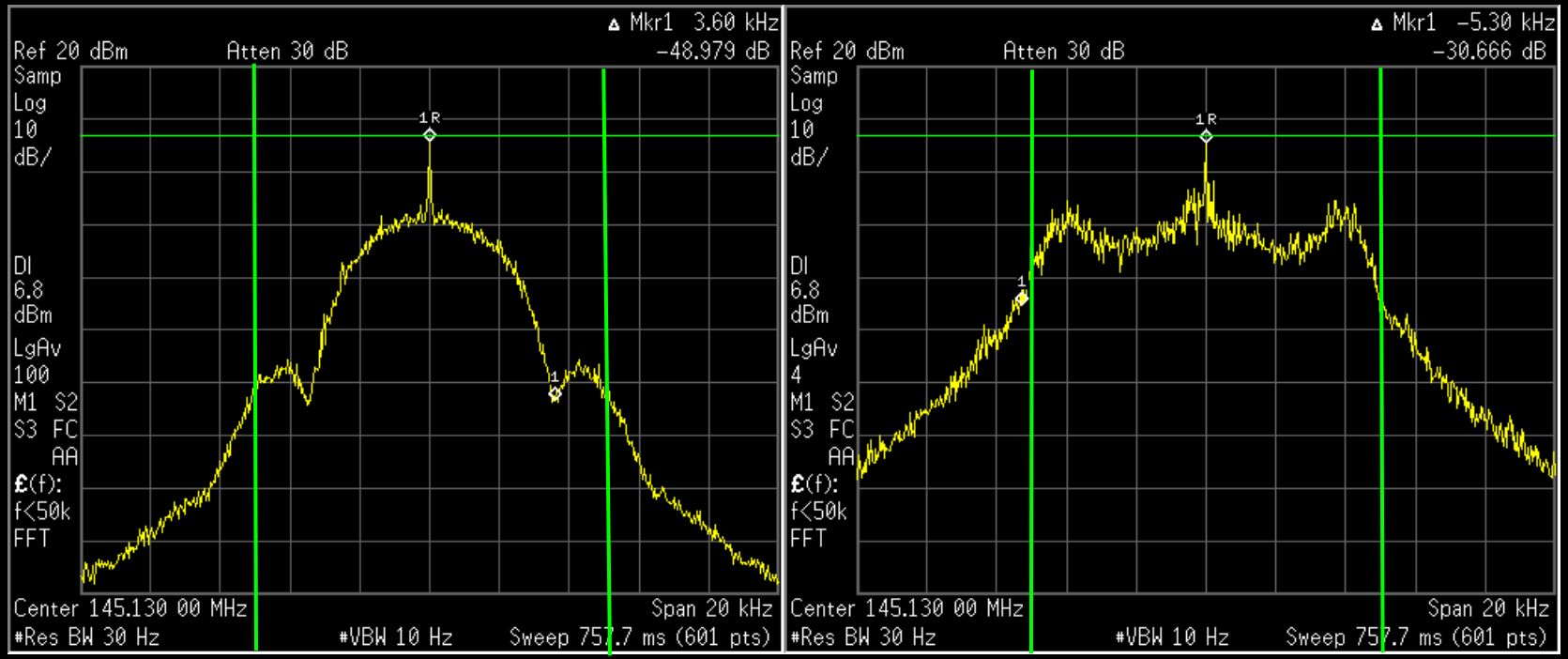


FSK: Frequency Shift Keying

GMSK: Gaussian Mean Shift Keying

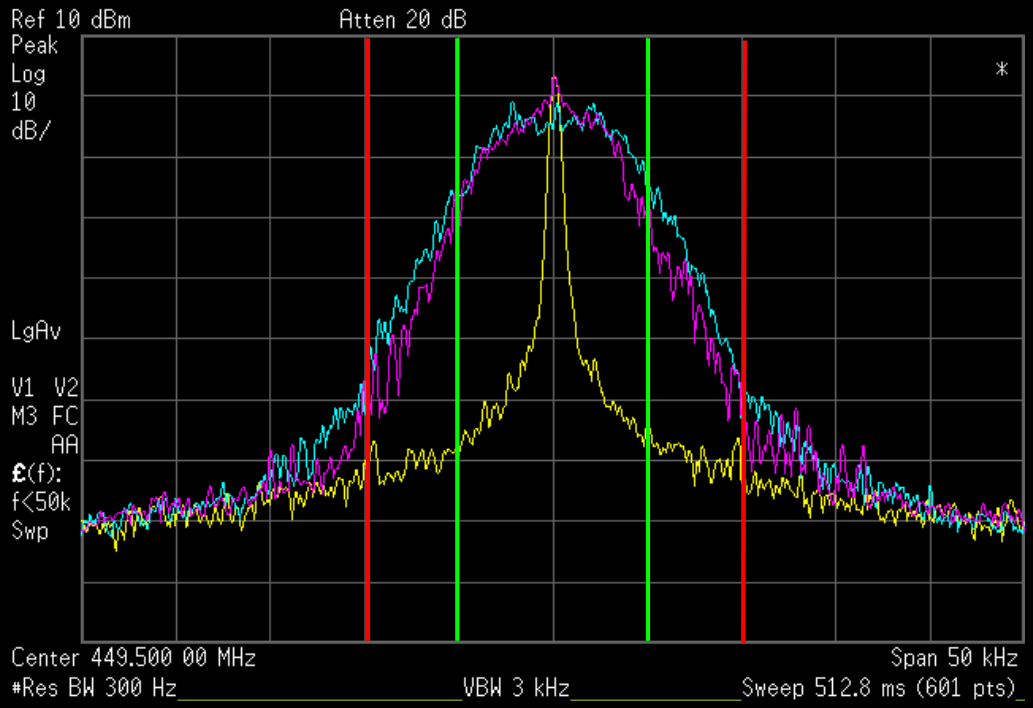
C4FM: Constant Envelope 4-Level FM

Spectrum Examples - Dstar & FM



10 KHz span in green

C4FM Spectrum



- The **Magenta** (purple) trace is the C4FM signal.
- The **Cyan** (blue-ish) trace is a +/- 5 kHz analog FM signal heavily modulated by a male voice.
- The **Yellow** trace is the same transmitter with no modulation present.
- 20 KHz span in red
- 10 KHz span in green

Bandwidth

Bandwidth: Modulation index

h = Freq Dev / Audio Freq

Broadcast FM = 75/20 = 3.75

Ham FM = 5/3.5 = 1.4

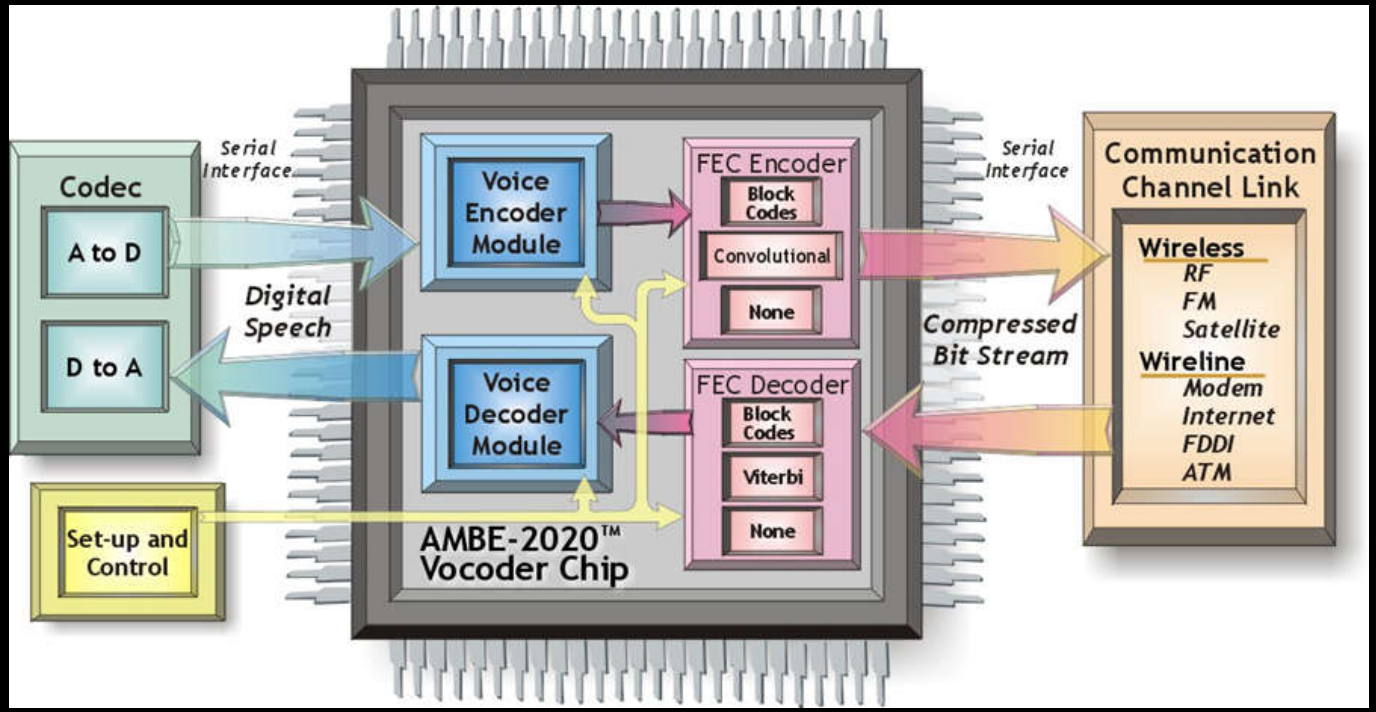
C4FM = 1.0

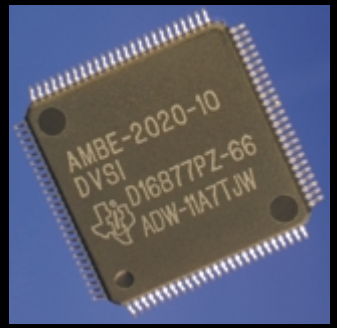
Narrow band FM = 2.5/3.5 = 0.7

Dstar = 0.5

Increasing modulation index by 2 increases the signal to noise by 8!

AMBE Vocoder





Popular Modes

Dstar

P25 Phase 1 & 2

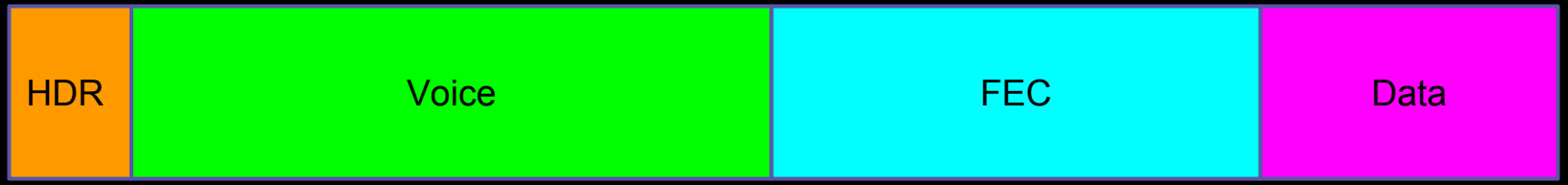
MotoTurbo

DMR (Tier I (pDMR), II, III)

IDAS/NXDN

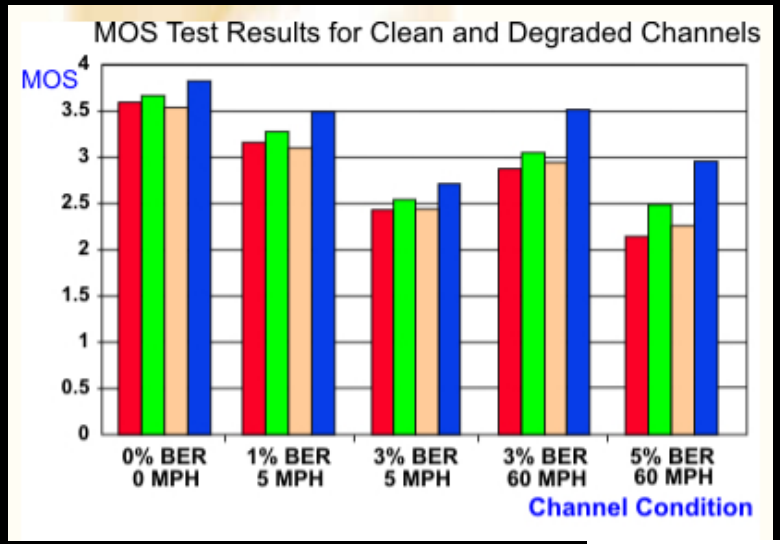
Fusion

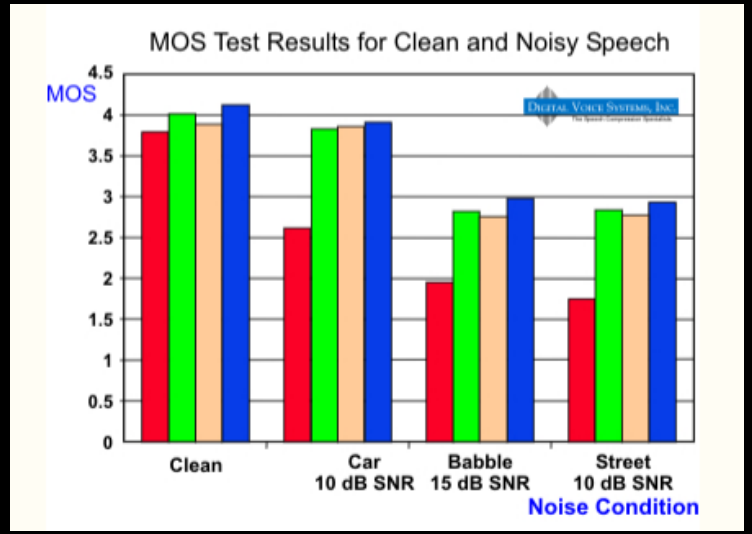
Bit Rate

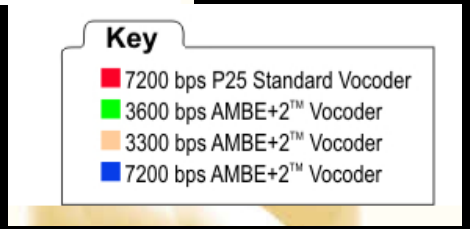


Mode	Bit Rate	Voice	Bandwidth	Notes
Dstar	4,800	2,400	10 KHz	
IDAS/NXDN	4,800	3,600	6.25 KHz	
DMR	7,200	2,400?	12.5 KHz	TDMA, 2 voice channels
Fusion DN	9,600	4,800	12.5 KHz	Supports digital, more FEC
Fusion VW	9,600	7,200?	12.5 KHz	Better sounds, lower FEC

Subjective Vocoder Performance







Dstar Performance

Quality of analog signal	Link to recording	Comments about analog signal quality	Comments about digital signal quality
12dB unweighted SINAD (13dB CCITT)	12dB SINAD Test	Analog signal is copyable by the majority of listeners with little or no difficulty.	Noticeable degradation of the digital stream, but still generally copyable speech. ***At this level, it takes 2-5 seconds before signal lock is achieved.***
7dB unweighted SINAD (10dB CCITT)	7dB SINAD Test	Analog signal is quite noisy: Copyable by experienced operators with little or no difficulty and with only minor difficulty by inexperienced listeners.	There was considerable degradation of the digital stream resulting in "recognizable but mostly uncopyable" speech. ***At this level, it takes 5-7 seconds before signal lock is achieved.***
3dB unweighted SINAD (5dB CCITT)	3dB SINAD Test	Analog signal is very noisy: Generally copyable by experienced listeners, with some difficulty by inexperienced listeners.	The receiver would not lock on digital signal: Signal was briefly boosted 10dB to force lock (during the "This is K7" portion) and then reduced to the original level.

Table 2: Comparing SINAD of an analog signal *(as received in "Wide" FM mode)* with

From http://utahvhfs.org/dstar_testing.html

Fusion Performance

- Improved audio quality (higher bit rate)
- More robust (fewer and shorter dropouts)
- Easier (much easier) to use!!!!
- Better suited for Ham needs
- Follows where industry is going (GMSK is no longer used)
- Has a future (TDMA), simplex repeaters

References

“A Digital Communications Guide for Amateur Radio Operators”, Yaesu

“P25 Radio Systems”, Daniels Electronics

Utah VHF Society, http://utahvhfs.org/

“All About Modulation”, www.complextoreal.com

“D-Star Uncovered”, AE5PL

http://www.sigidwiki.com/wiki/Signal_Identification_Guide

http://www.dvsinc.com/index.htm

http://www.etsi.org/technologies-clusters/technologies/digital-mobile-radio

What's Next?

We've been given technology. What can *we* do with it?
Experiment, learn, exchange, grow - our own "iPhone"

Q&A