



How to Make HD Radio Easy for Broadcasters

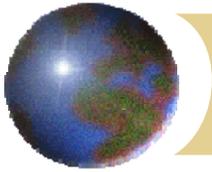
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Continental Electronics Corporation



Topics for Discussion

- **The nuisances of new technologies**
 - ▶ User-hostile hardware & software

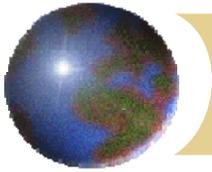
- **IBOC-specific irritations**
 - ▶ Confusing or ambiguous jargon
 - ▶ too many boxes
 - ▶ too many interfaces

- **Technology “gotchas” and solutions**

- **What can be done to make this easy?**

- **Can we learn and apply anything from DTV?**

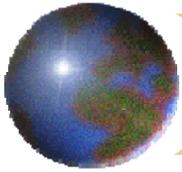




How to make HD Radio Easier

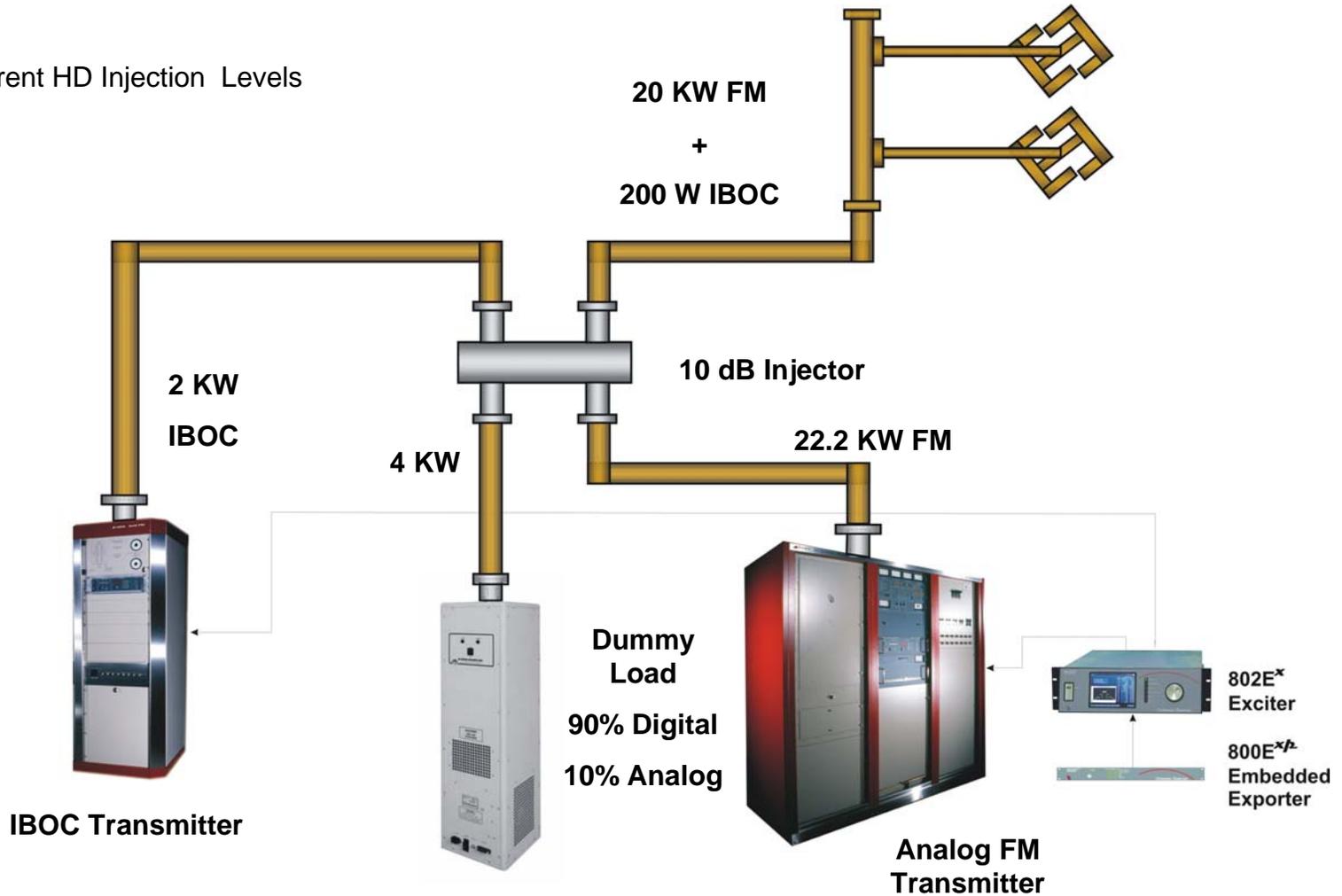
- **EMBEDDED EXPORTER**
 - ▶ Confusing misnomer – may be external or internal
- **USER-FRIENDLY SOFTWARE**
 - ▶ GUI and remote access
 - ▶ Reliable Linux operating system
- **COMPUTER-INDEPENDENT HARDWARE**
 - ▶ Signal path operates without a computer
- **ADAPTIVE EQUALIZATION TECHNOLOGY**
 - ▶ Squeezes more efficiency and power from PA
- **PERFORMANCE MONITORING**
 - ▶ Reduces requirements for special test equipment

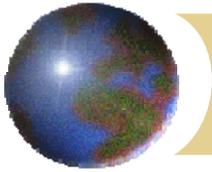




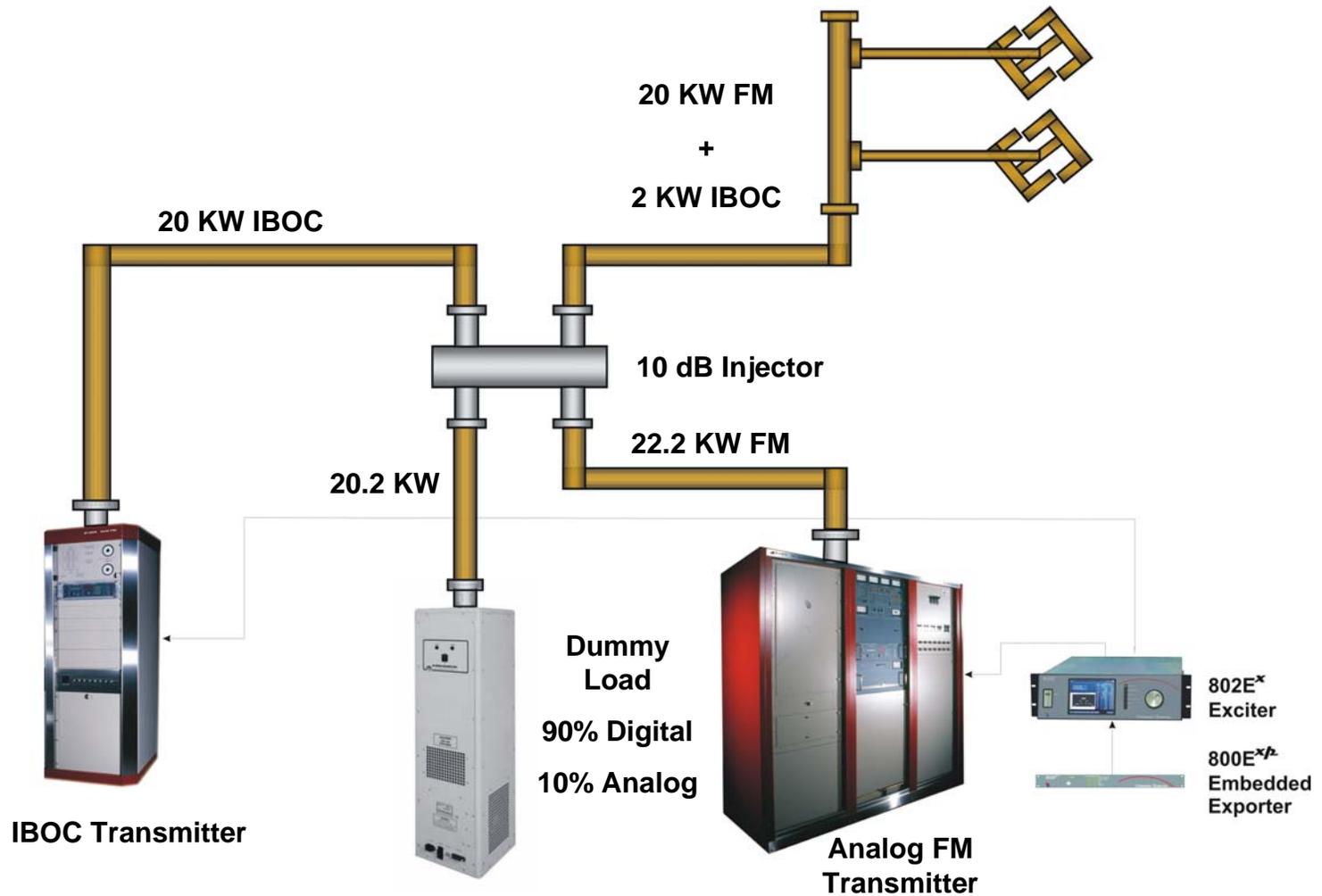
High Level Combined IBOC FM System With -20 dBc (1%) Injection Level

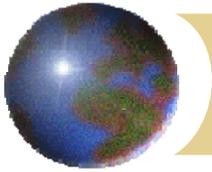
Current HD Injection Levels



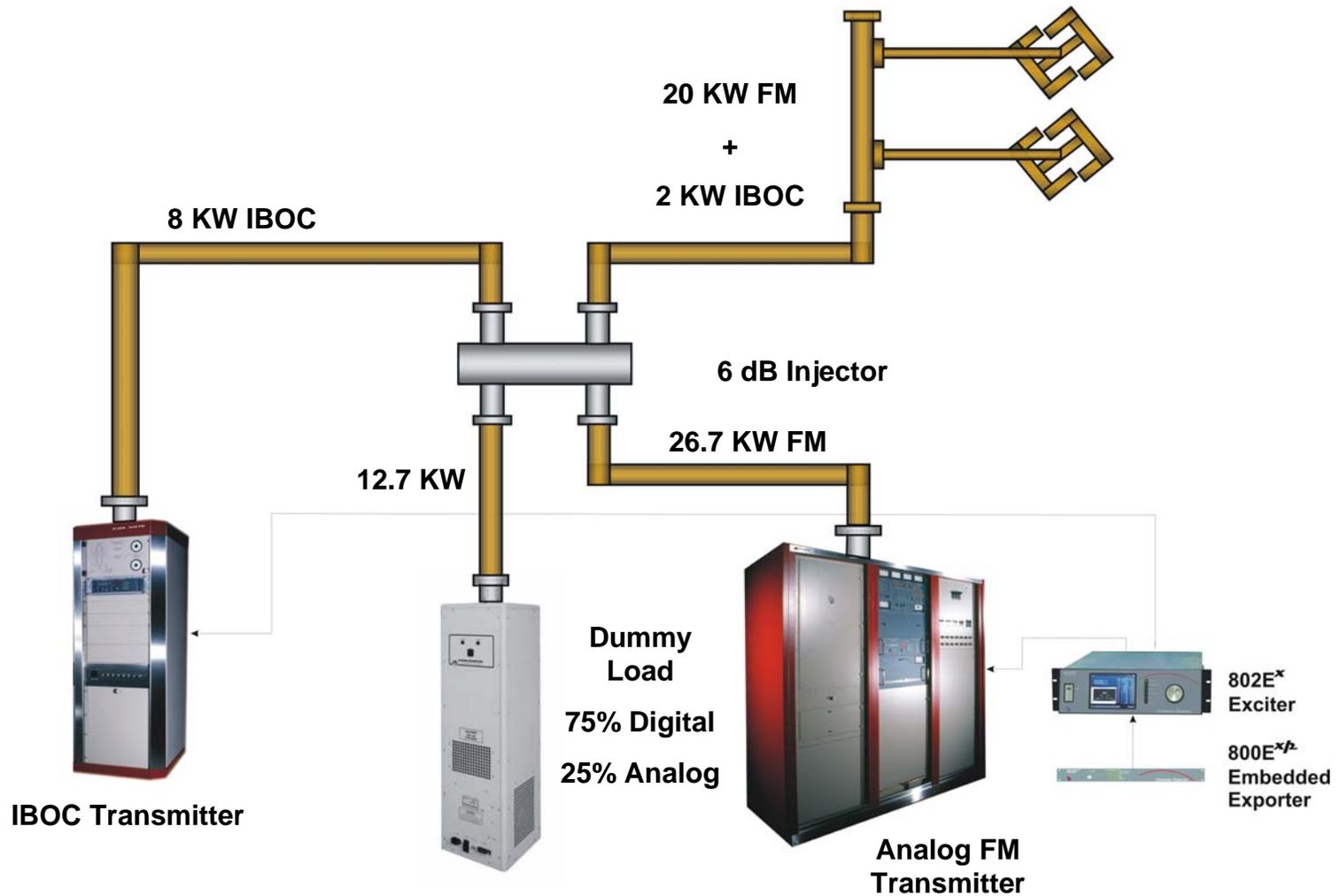


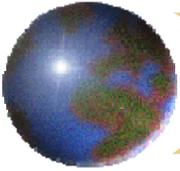
High Level Combined IBOC FM System With -10 dBc (10%) Injection Level



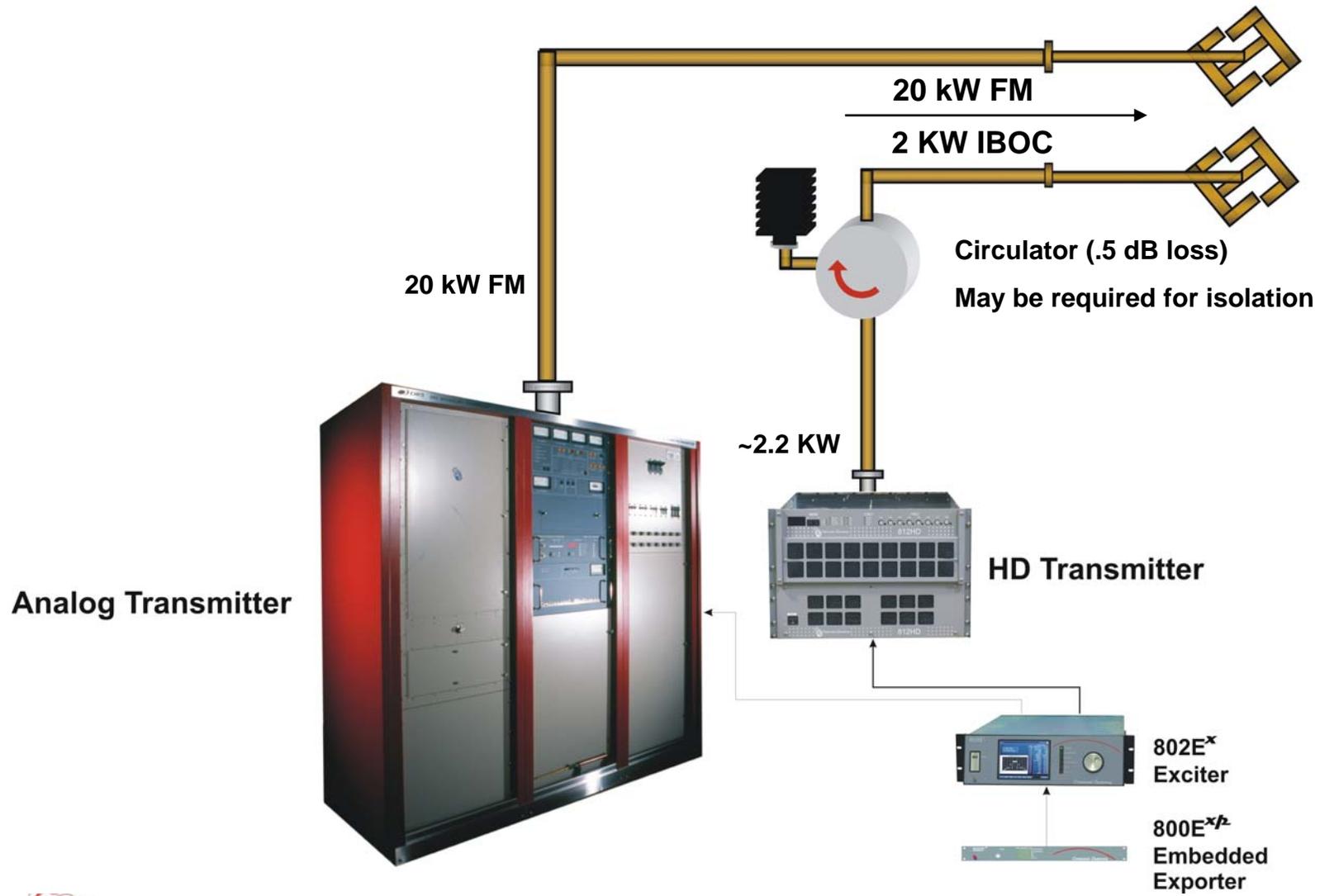


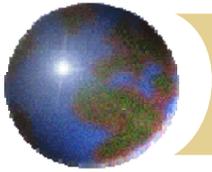
High Level Combined IBOC FM System With -10 dBc (10%) Injection Level





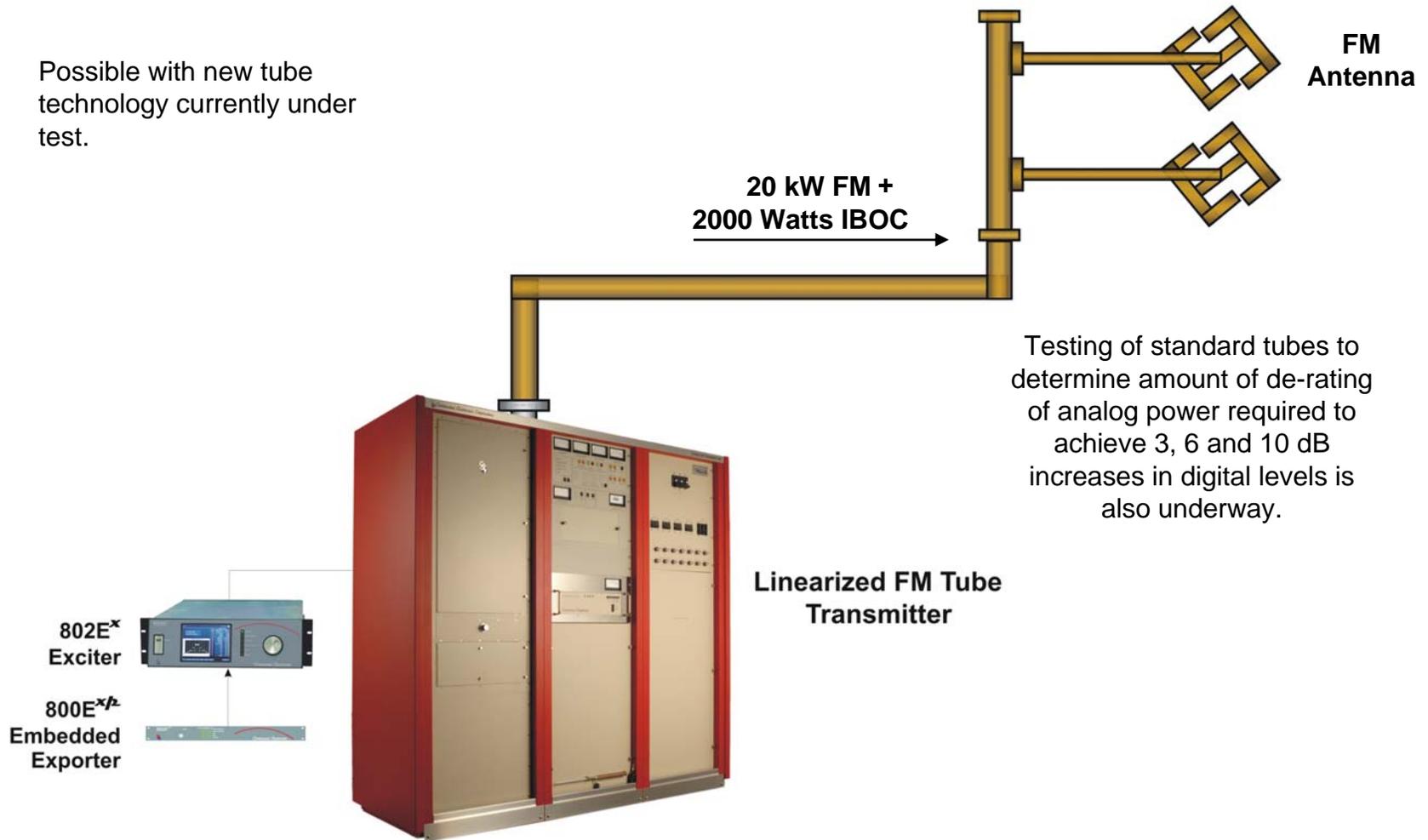
Dual Antenna or Dual Input Antenna

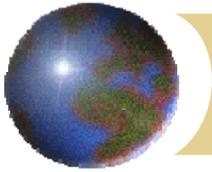




Low Level Combined IBOC FM System (Under Development)

Possible with new tube
technology currently under
test.



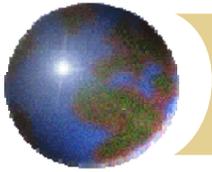


COMMON AMPLIFICATION CAPABILITY

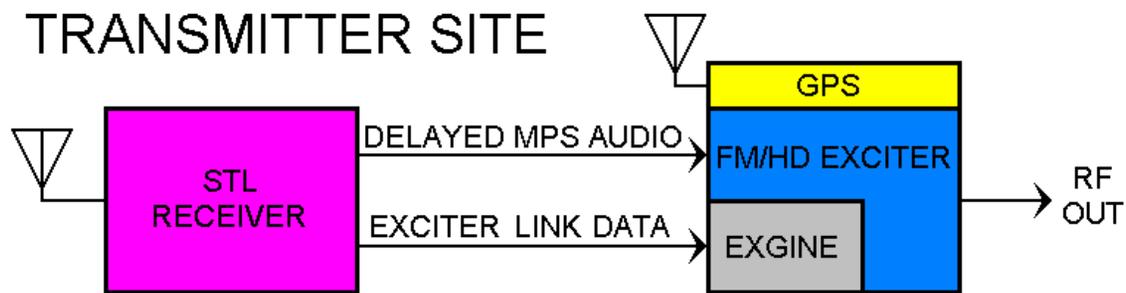
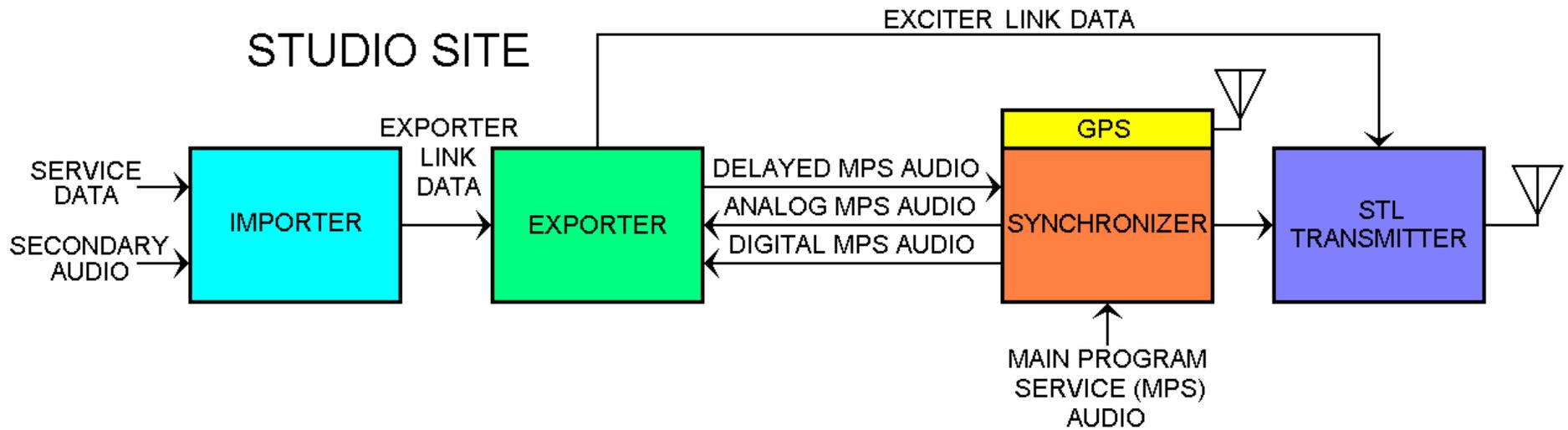
- **TUBE TRANSMITTER CAPABILITIES AT 10% HD INJECTION**
 - ▶ **Existing HD Transmitters**
 - ◆ TPO – 10kW Analog*
 - ◆ Efficiency – 40%*
 - ▶ **Existing HD Transmitters w/ Modifications**
 - ◆ TPO – 12.5kW*
 - ◆ Efficiency – 45%*
 - ▶ **New HD Transmitters**
 - ◆ TPO – 17.5kW to 25kW*
 - ◆ Efficiency – 60%*

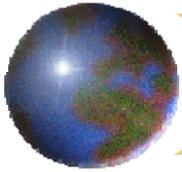
***EXPECTED PERFORMANCE BUT NOT
GUARANTEED IN ALL CASES**





DOING IBOC THE OLD WAY

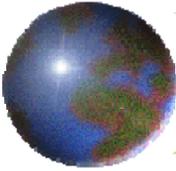




EMBEDDED EXPORTER

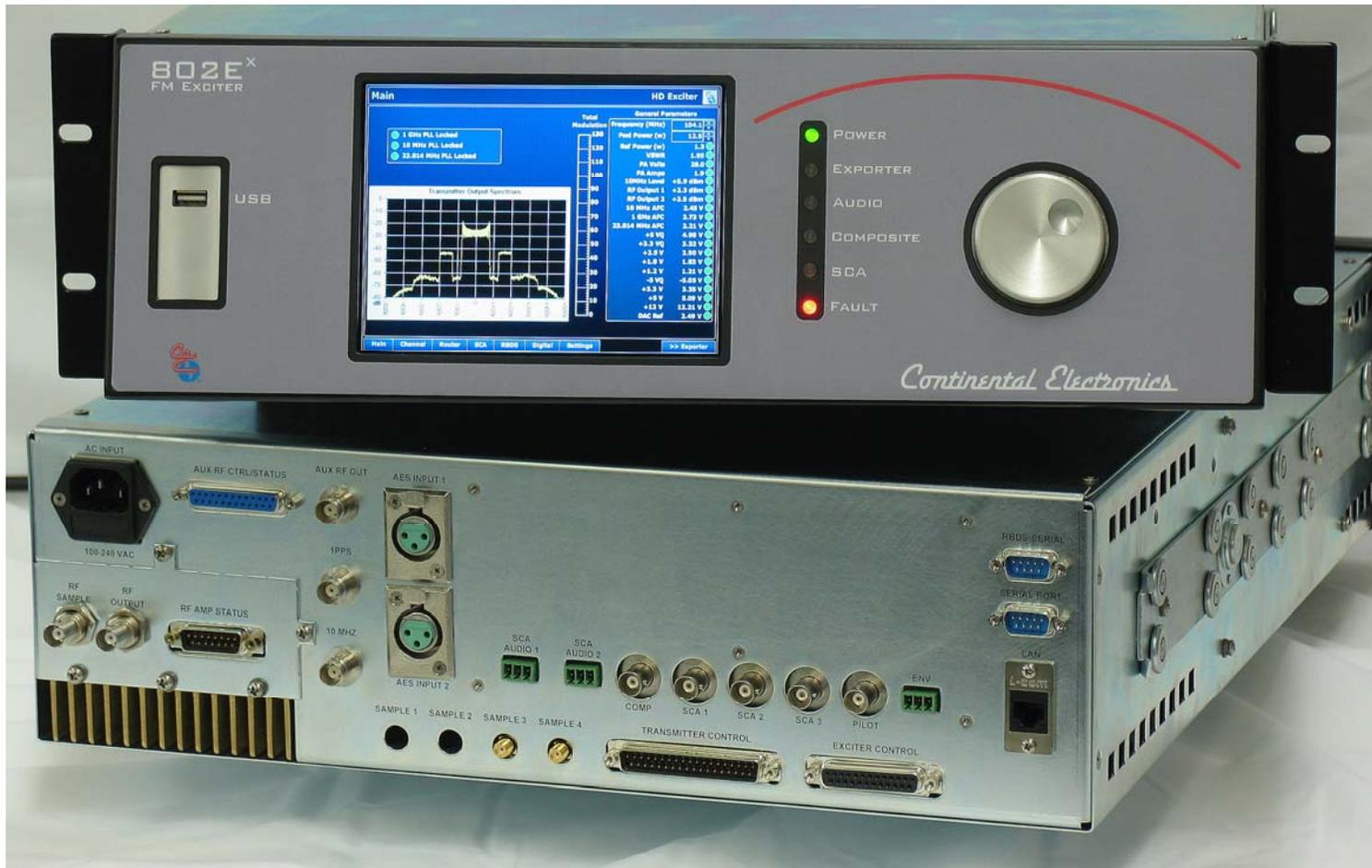
- **EASIEST & FASTEST PATH TO HD**
- **LOW INITIAL INVESTMENT \$\$\$**
- **INVESTMENT PROTECTED ROADMAP**
- **HIGH RELIABILITY**
- **LOW COST TO OPERATE**
- **BETTER – CHEAPER – FASTER :**
EMBEDDED EXPORTER HAS IT ALL!!!!

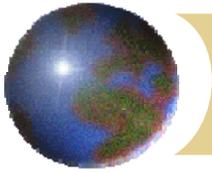




EMBEDDED INTO HD EXCITER

- **FASTEST ANALOG TO HD UPGRADE**

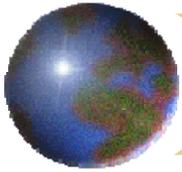




EMBEDDED EXPORTER

- HD ROADMAP THAT PROTECTS YOUR INVESTMENT
- FLEXIBLE CONFIGURATIONS
- SIMPLE OPERATOR INTERFACE
- EASY UPGRADE VIA NETWORK OR USB





EMBEDDED EXPORTER FEATURES

• HIGH RELIABILITY

- ▶ Embedded Exporter reduces component count ~90%
- ▶ No hard drive
- ▶ 100% non-volatile memory

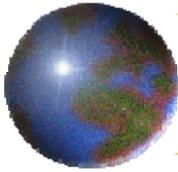
• SMALL SIZE (1RU)

- ▶ 80% power savings

• ADDITIONAL FEATURES

- ▶ Ballgame Mode (low analog delay)
- ▶ Analog STL Backup
- ▶ No GPS Antenna Required





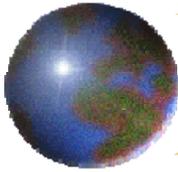
WEB BASED USER INTERFACE

The screenshot shows a web browser window with the address bar containing the path: C:\Documents and Settings\dldickey\My Documents\I... The browser interface includes standard navigation buttons (Home, Back, Forward, Print, Page, Tools) and a search bar. The main content area is titled "Status" and "HD FM Exporter" with a small globe icon. A status panel on the left lists several indicators with corresponding colored circles:

- Connected (Green circle)
- Audio Present (Green, Yellow, Red circles)
- Audio Framing (Green, Yellow, Red circles)
- I2E (Green, Yellow, Red circles)
- E2X (Green, Yellow, Red circles)
- Status (Green, Yellow, Red circles)

At the bottom of the interface, there is a navigation menu with buttons for "Main", "Audio", "Station Information", "Station Schedule", "Setup", and ">> Exciter". The browser's taskbar at the bottom shows "My Computer" and a zoom level of "100%".

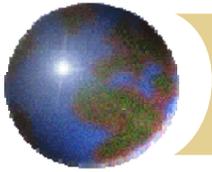




WEB BASED USER INTERFACE

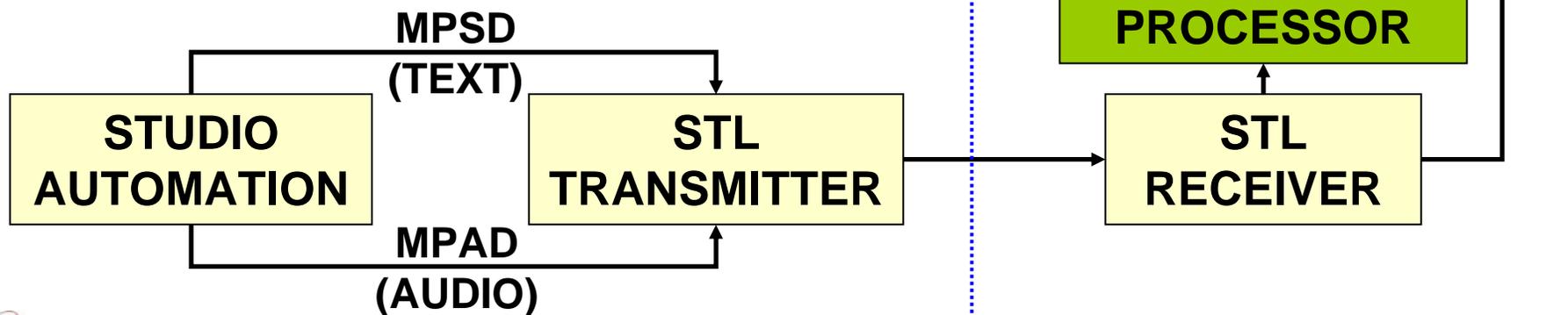
The screenshot shows a web browser window displaying the 'HD FM Exporter' interface. The browser's address bar shows a local file path: 'C:\Documents and Settings\dldickey\My Documents\I...'. The interface is titled 'Audio' and 'HD FM Exporter'. It features several control panels: 'Audio Diversity' with a 'Blending' dropdown; 'Delay' with 'Samples' (99000) and 'Step Size' (0) spinners, and 'Total (secs)' and 'Current (secs)' input fields; 'Ramp Rate' with a 'Ramp Rate (samples / sec)' spinner (0) and buttons for 'Ramp Up', 'Ramp Down', and 'Immediate'; 'Primary Carrier', 'MPS Source', and 'Level Adjust' (0) dropdowns and spinners. On the right, there is an 'Audio Level' meter ranging from 0 to 100. At the bottom, there are navigation buttons: 'Main', 'Audio', 'Station Information', 'Station Schedule', 'Setup', and '>> Exciter'. The Windows taskbar at the bottom shows 'My Computer' and '100%' zoom.

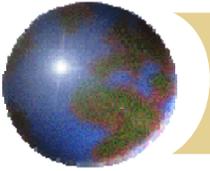




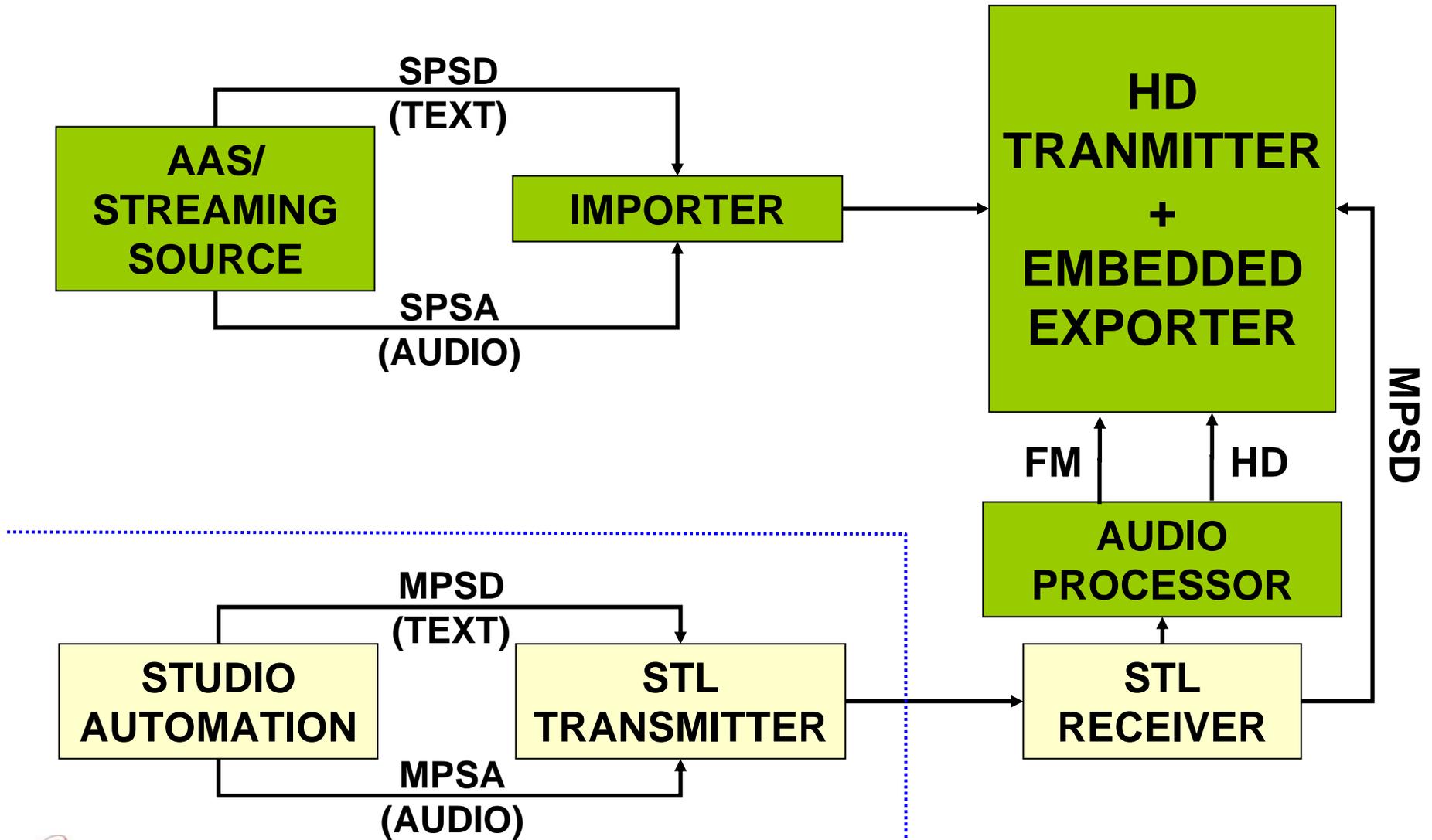
EASIEST POSSIBLE HD UPGRADE

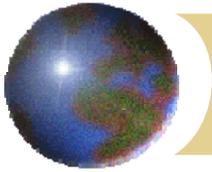
- **HD TRANSMITTER**
 - ▶ HD Exciter w/ Embedded Exporter
- **HD AUDIO PROCESSOR**
- **STANDARD STL**



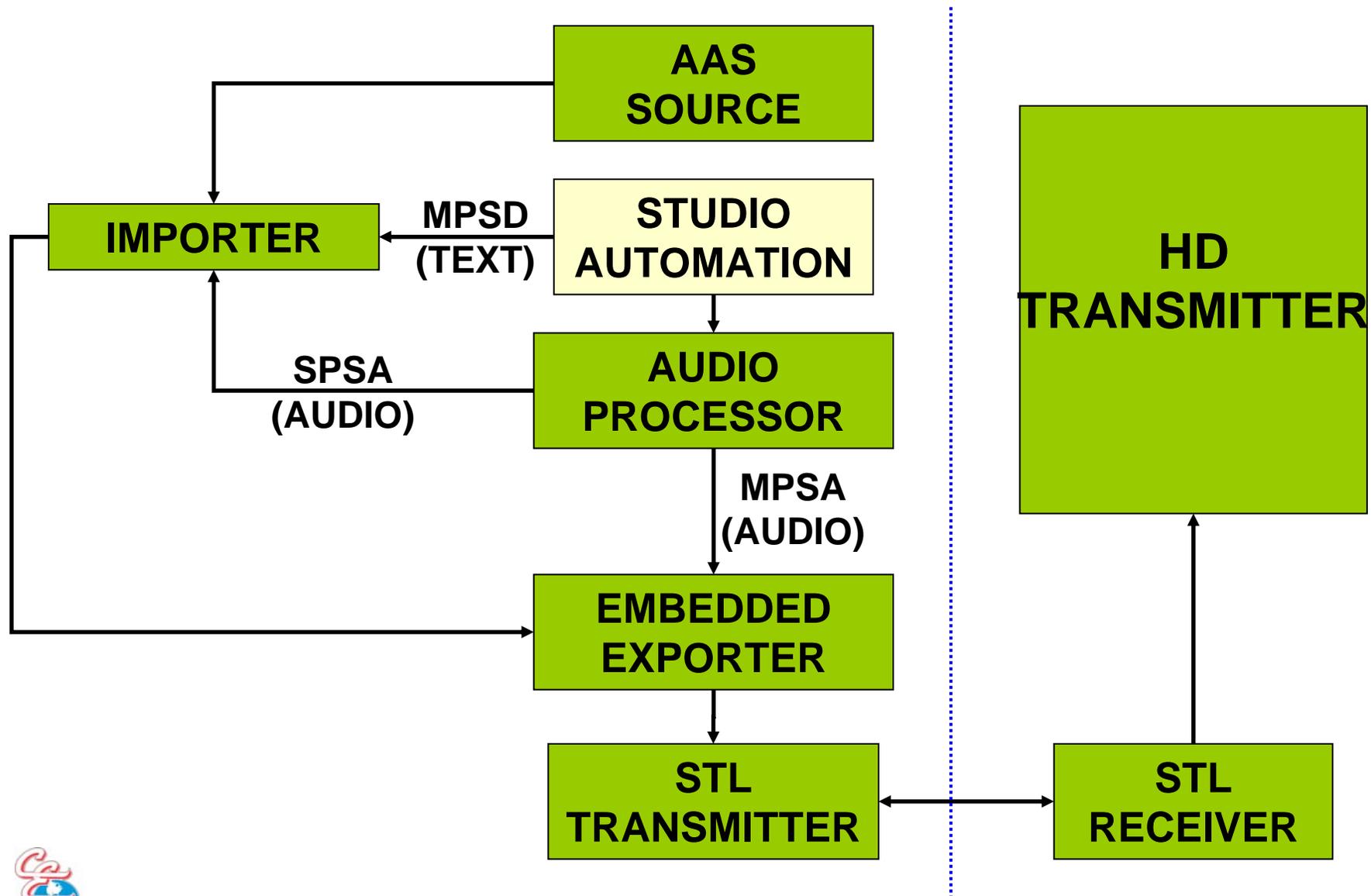


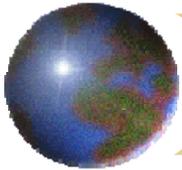
HD ROADMAP





HD ROADMAP (cont.)

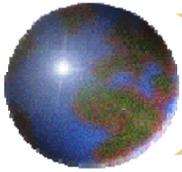




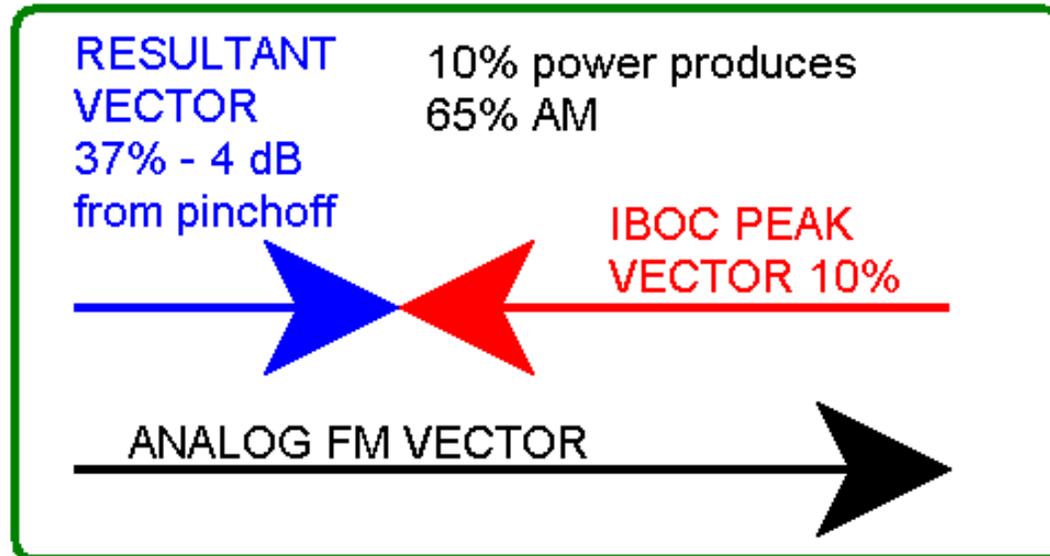
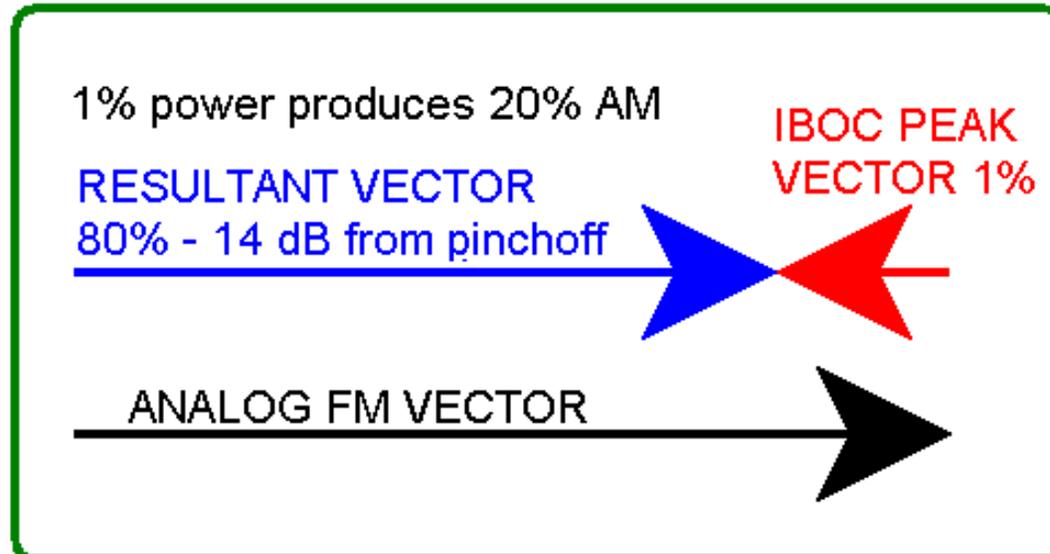
ENVELOPE MODULATION vs. DIGITAL POWER

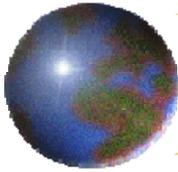
Digital Power	Digital voltage (RMS, normalized)	Digital voltage (peak) (6 dB PAR)	Envelope Modulation (AM)	PEP (% of analog)
1%	0.1	0.2	20%	144%
10%	0.316	0.632	63.2%	266%



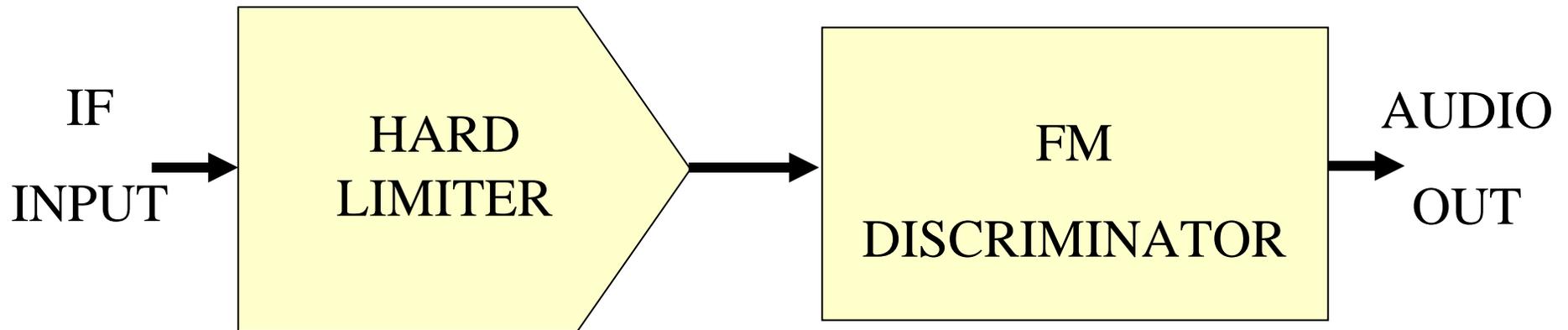


ENVELOPE MODULATION and PINCHOFF



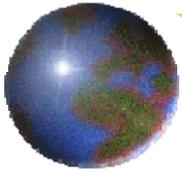


ANALOG FM RECEIVER



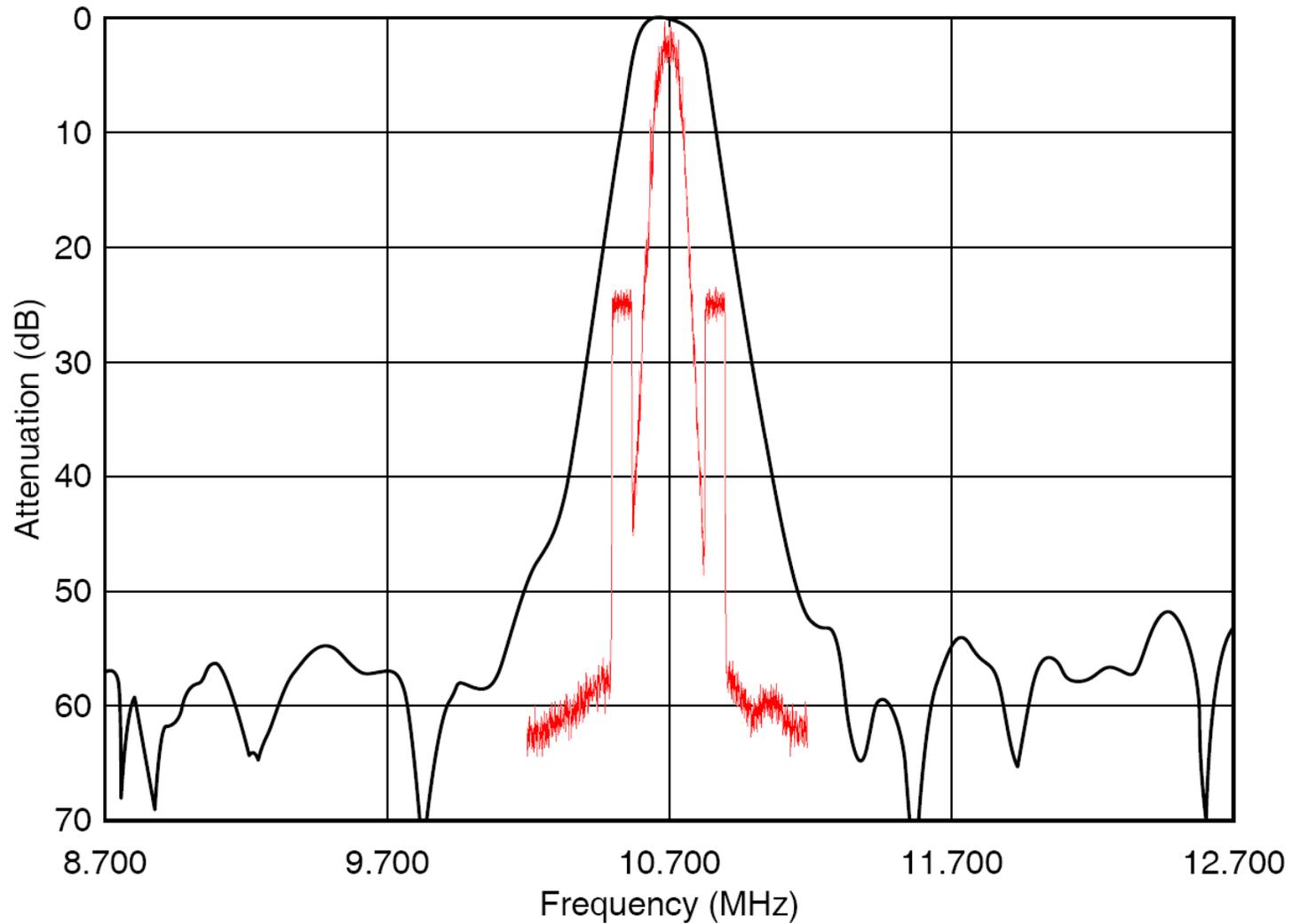
- **Hard limiter – its gain is the reciprocal of its input amplitude**
- **Envelope pinchoff (zero envelope) creates noise bursts**

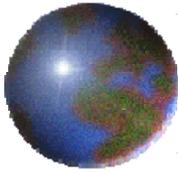




IBOC in Narrow Murata IF Filter

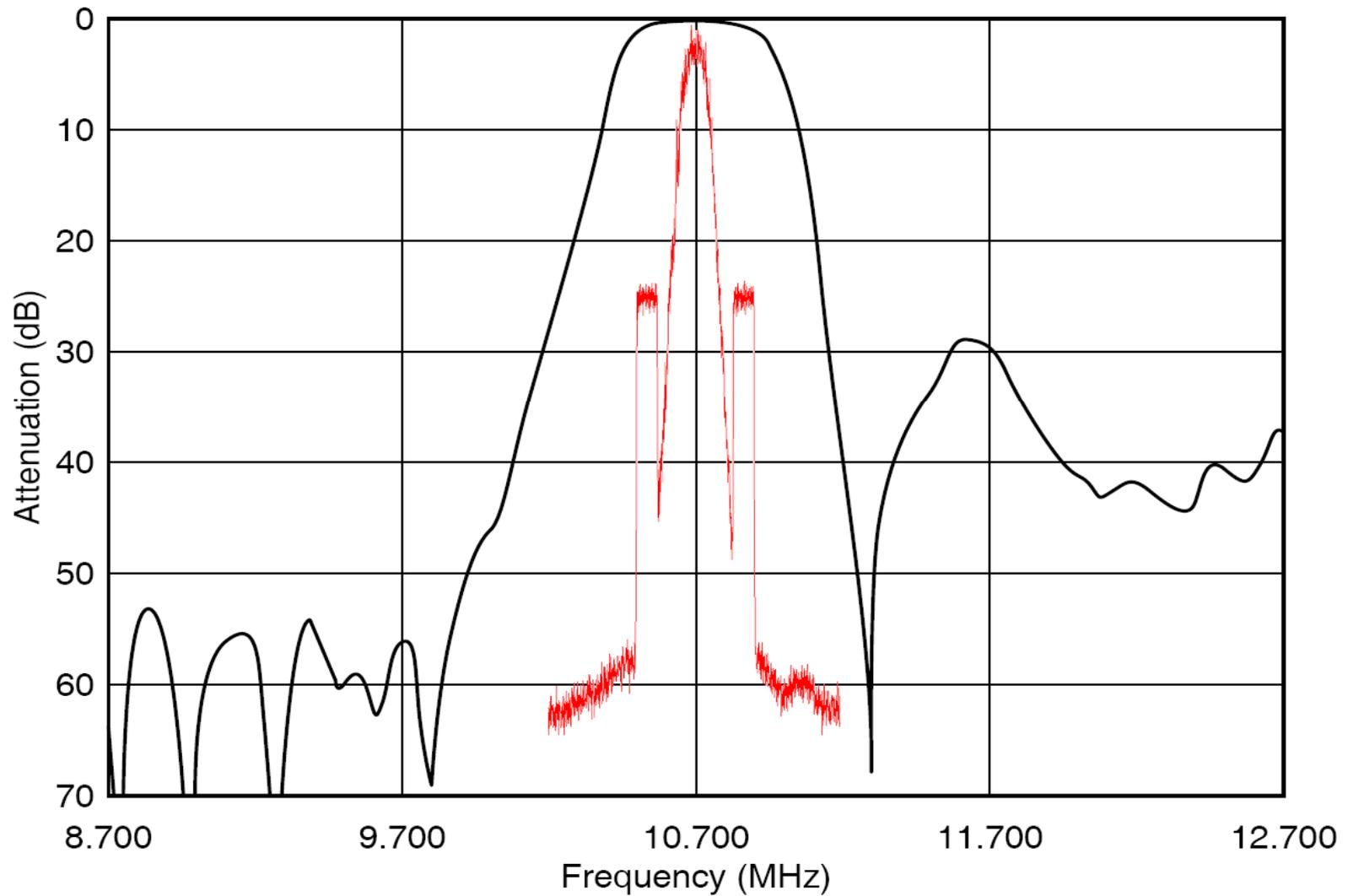
SFELF10M7GA00-B0

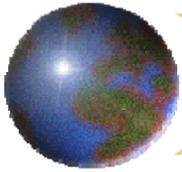




IBOC and WIDE MURATA IF FILTER

SFELF10M7DF00-B0



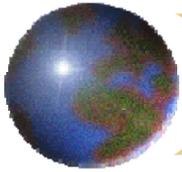


UNINTENDED CONSEQUENCES OF HIGHER DIGITAL POWER

- **ADJACENT CHANNEL INTERFERENCE**
- **MULTIPATH SUSCEPTIBILITY (HIGH AM)**
- **RECEIVER BANDWIDTH ISSUES**
- **ANALOG SELF-NOISE & RECEIVER STEREO BLENDING**
- **TRANSMITTER EFFICIENCY & PEAK POWER**

Is there an alternative?

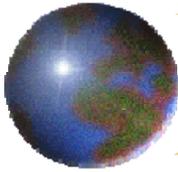




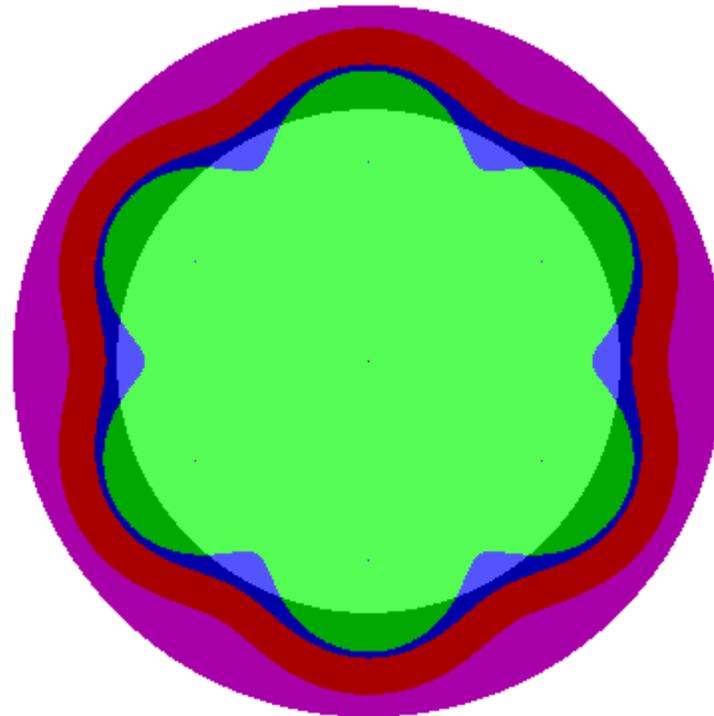
WHAT IS A SINGLE FREQUENCY NETWORK?

- **Multiple transmitters cover an area**
- **Receivers may receive signals from multiple transmitters simultaneously (multipath)**
- **Also known as Distributed Transmission (DTx)**
- **All transmitters are synchronized in terms of:**
 - ▶ Frequency
 - ▶ Timing
 - ▶ Data/symbols (digital)
 - ▶ Deviation (analog)
- **Advantages:**
 - ▶ Much lower ratio of interference area to coverage area
 - ▶ Lower overall transmitter power to cover an area





SFN: main TX at 1%, boosters at 10%



MAGENTA: SINGLE 10% TRANSMITTER DIGITAL INTERFERENCE ZONE

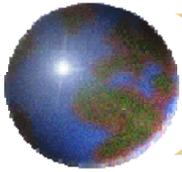
RED: SFN DIGITAL INTERFERENCE ZONE

BLUE: ANALOG COVERAGE

DARK GREEN: SFN DIGITAL COVERAGE

INNER HIGHLIGHT: SINGLE 10% TRANSMITTER DIGITAL COVERAGE

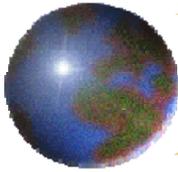




MORE INFORMATION ON SFNs

- **NPR has prepared an excellent report on SFNs, available for free download:**
- **National Public Radio, *Report to the Corporation for Public Broadcasting, Digital Radio Coverage & Interference Analysis (DRCIA) Project, Single Frequency Network Report, 2008. Download site:***
- **<http://www.nprlabs.org/research/drcia.php>**





TRANSMITTER DISTORTION MODELING

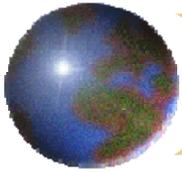
● INSTANTANEOUS MODEL

- ▶ PA gain may have AM to AM and AM to PM distortions
- ▶ PA gain depends only on the present instantaneous envelope level

● MEMORY DISTORTION MODEL

- ▶ PA gain may have AM to AM and AM to PM distortions
- ▶ PA gain depends on present **and PAST** envelope levels
- ▶ Applicable where tuned circuits are interspersed with nonlinear elements

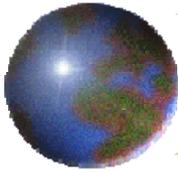




TYPES OF TRANSMITTER EQUALIZATION

- **BACKOFF (NO EQUALIZATION AT ALL)**
 - ▶ Inefficient, low output power
 - ▶ May require biasing close to class A operation
- **MANUALLY ADJUSTED ANALOG EQUALIZATION**
 - ▶ Difficult to adjust, limited capability
- **FIXED DIGITAL EQUALIZATION**
 - ▶ Capable of good equalization, but device aging and VSWR changes etc. degrade performance
- **ADAPTIVE INSTANTANEOUS NONLINEAR EQUALIZATION**
 - ▶ Tracks device aging, load changes, etc., good for 8-12 dB of linearity improvement
- **ADAPTIVE SIMULTANEOUS LINEAR & NONLINEAR EQUALIZATION**
 - ▶ Advanced technique, good for 15-20+ dB of linearity improvement





BENEFITS OF ADAPTIVE EQUALIZATION

- **LESS DISTORTION**

- ▶ Reduced adjacent and second adjacent interference
- ▶ Improved transmitted distortion – better digital coverage

- **HIGHER EFFICIENCY**

- ▶ Particularly important for proposals for higher digital power
- ▶ Allows reduced bias current (closer operation to class B)
- ▶ Desirable for purely digital signals
 - ◆ HD pure digital mode
 - ◆ DRM Plus

- **MORE POWER OUTPUT FROM A DEVICE**

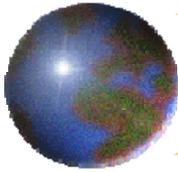
- **BETTER PERFORMANCE AS DEVICES AGE**

- **BETTER PERFORMANCE WITH LOAD VARIATIONS**

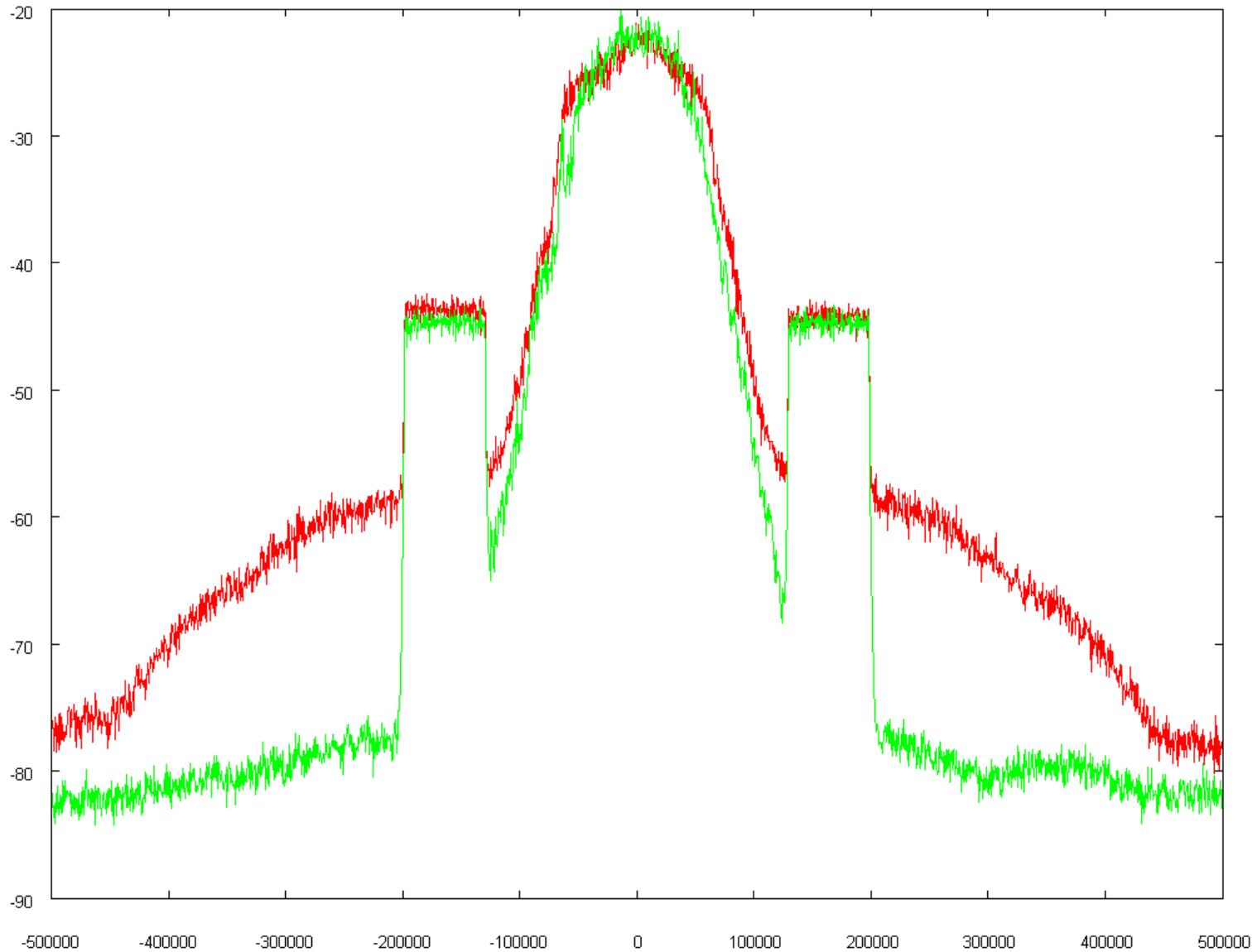
- **MORE RF POWER OUTPUT PER DOLLAR**

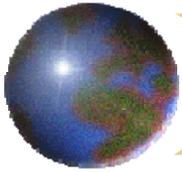
- ▶ Computers, FPGAs, and software are cheaper than big tubes and solid state amplifiers



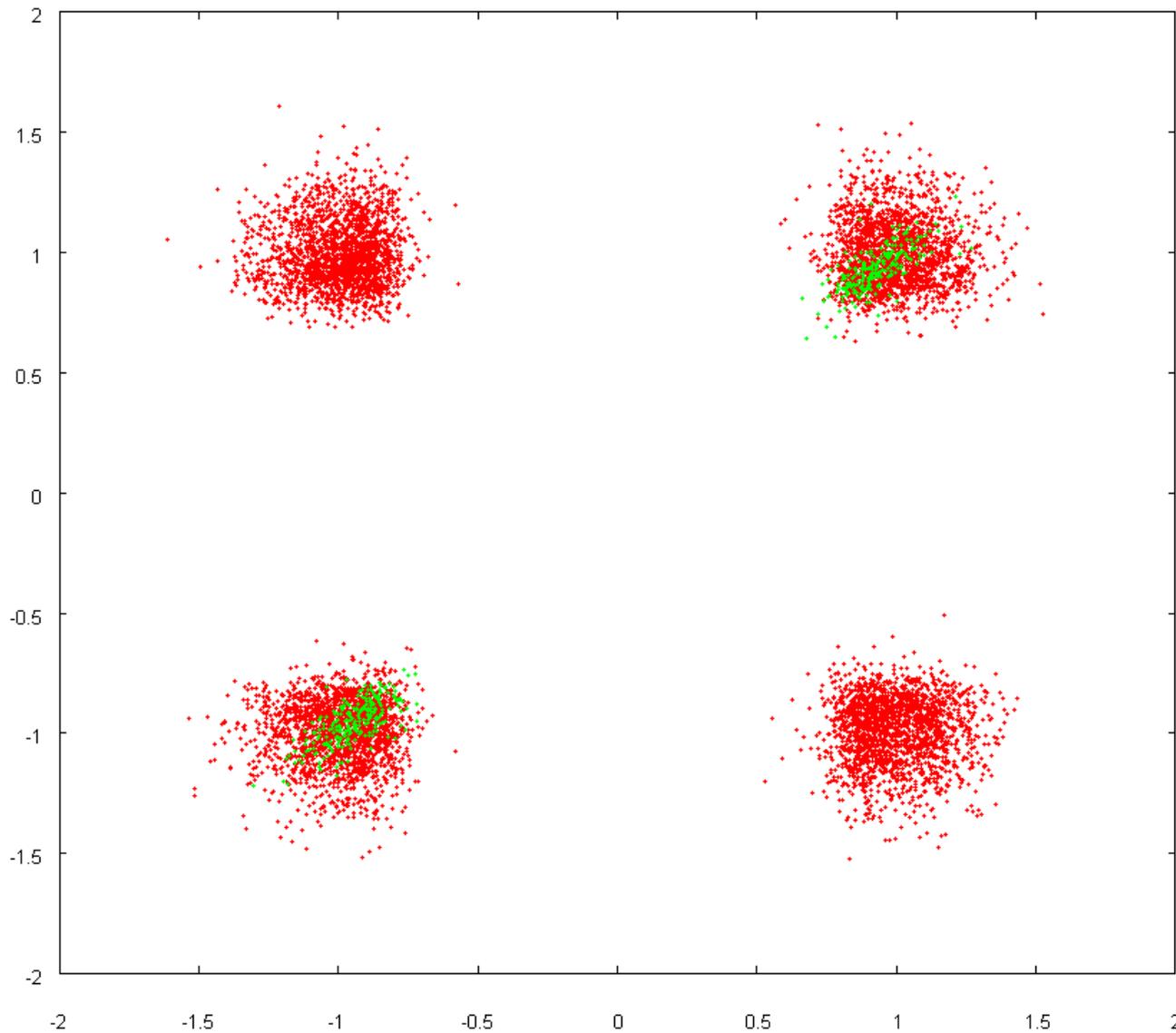


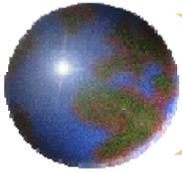
ADAPTIVE EQUALIZATION SPECTRUM





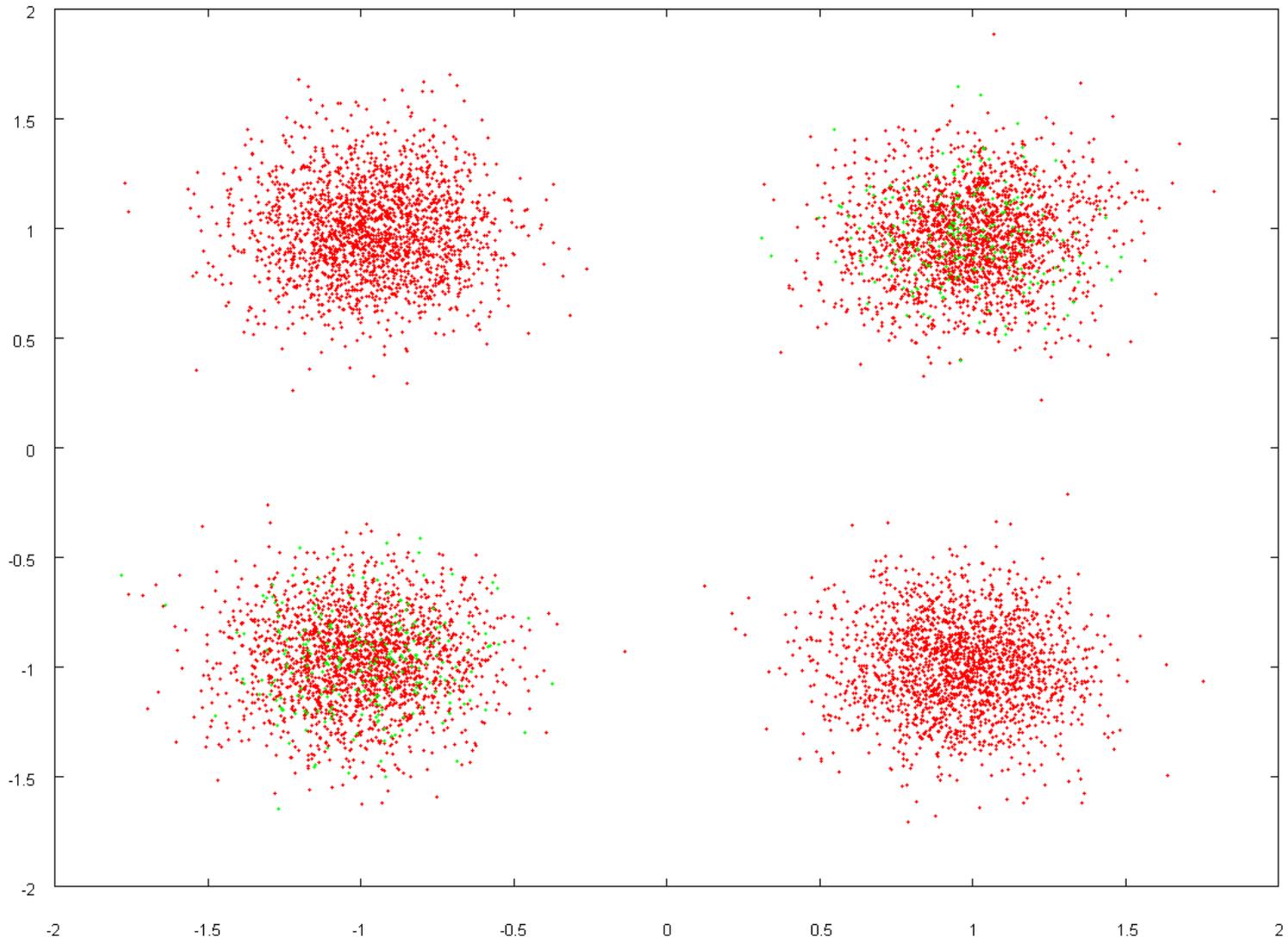
IBOC COFDM CONSTELLATION DISPLAY IDEAL SIGNAL WITH PAR

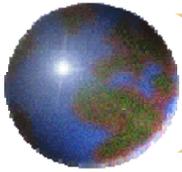




IBOC COFDM CONSTELLATION DISPLAY

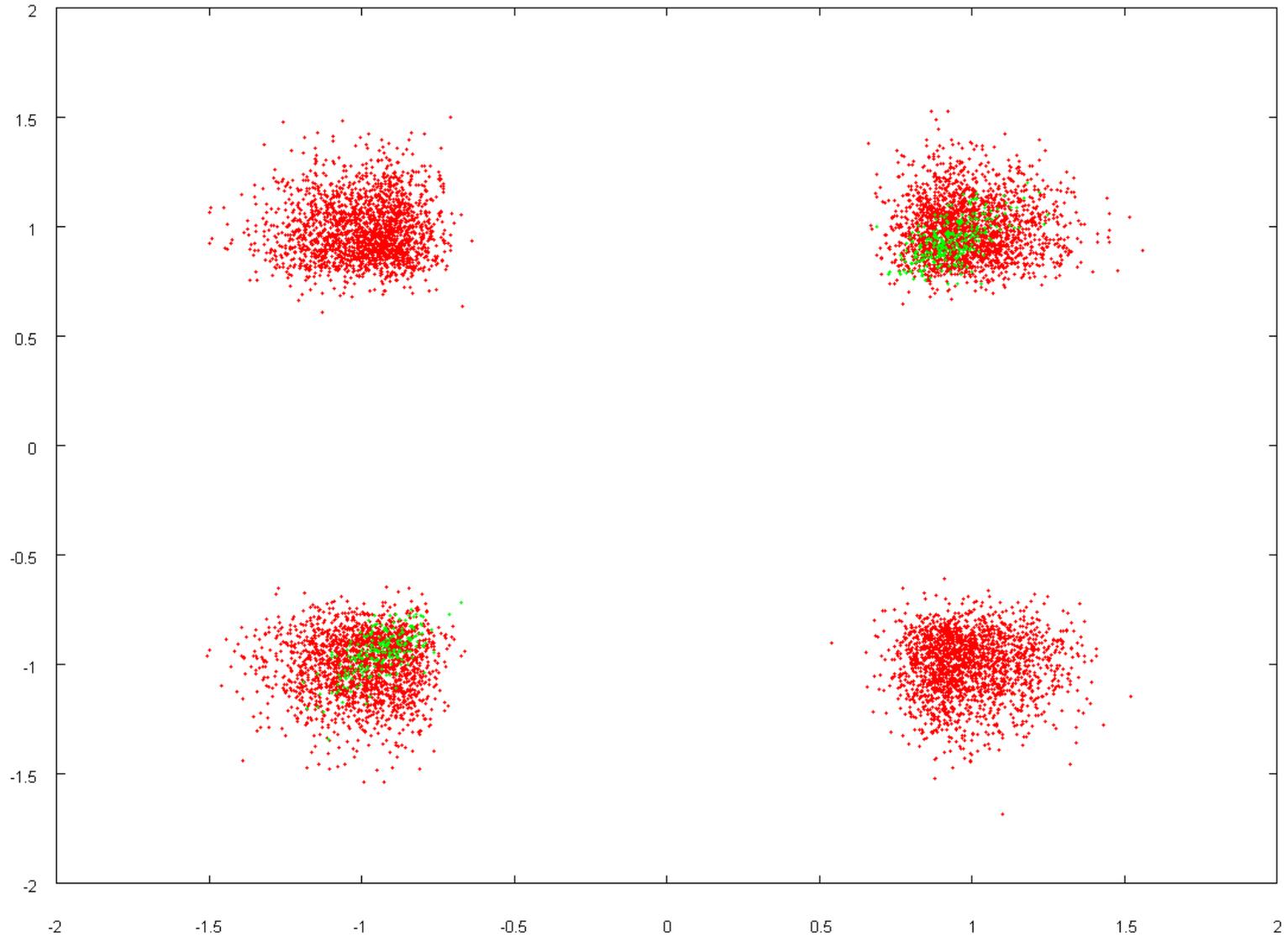
UNCORRECTED TRANSMITTER OUTPUT SIGNAL WITH PAR

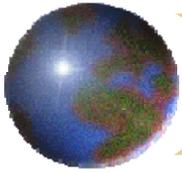




IBOC COFDM CONSTELLATION DISPLAY

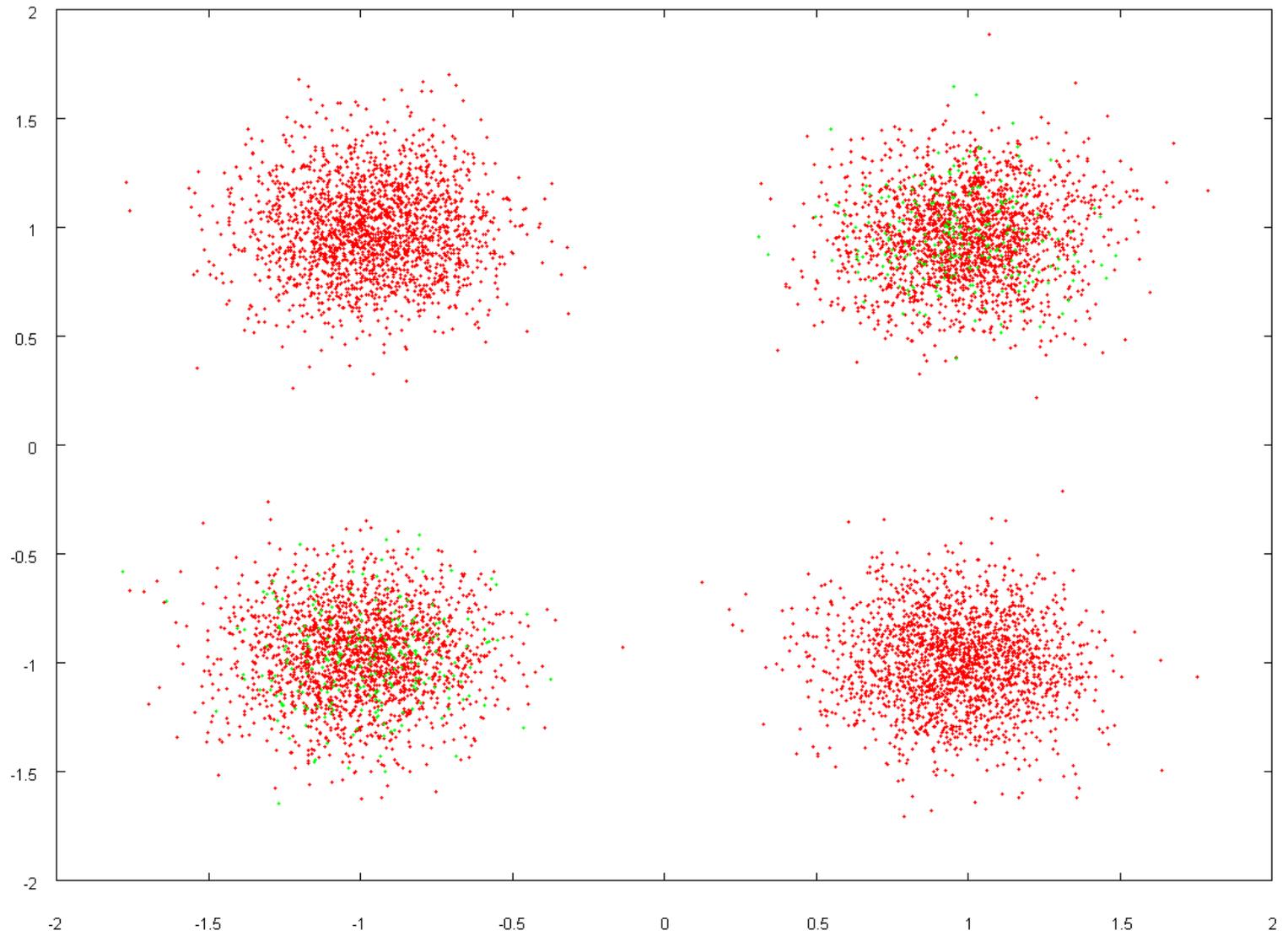
CORRECTED TRANSMITTER OUTPUT SIGNAL WITH PAR

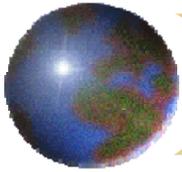




IBOC COFDM CONSTELLATION DISPLAY

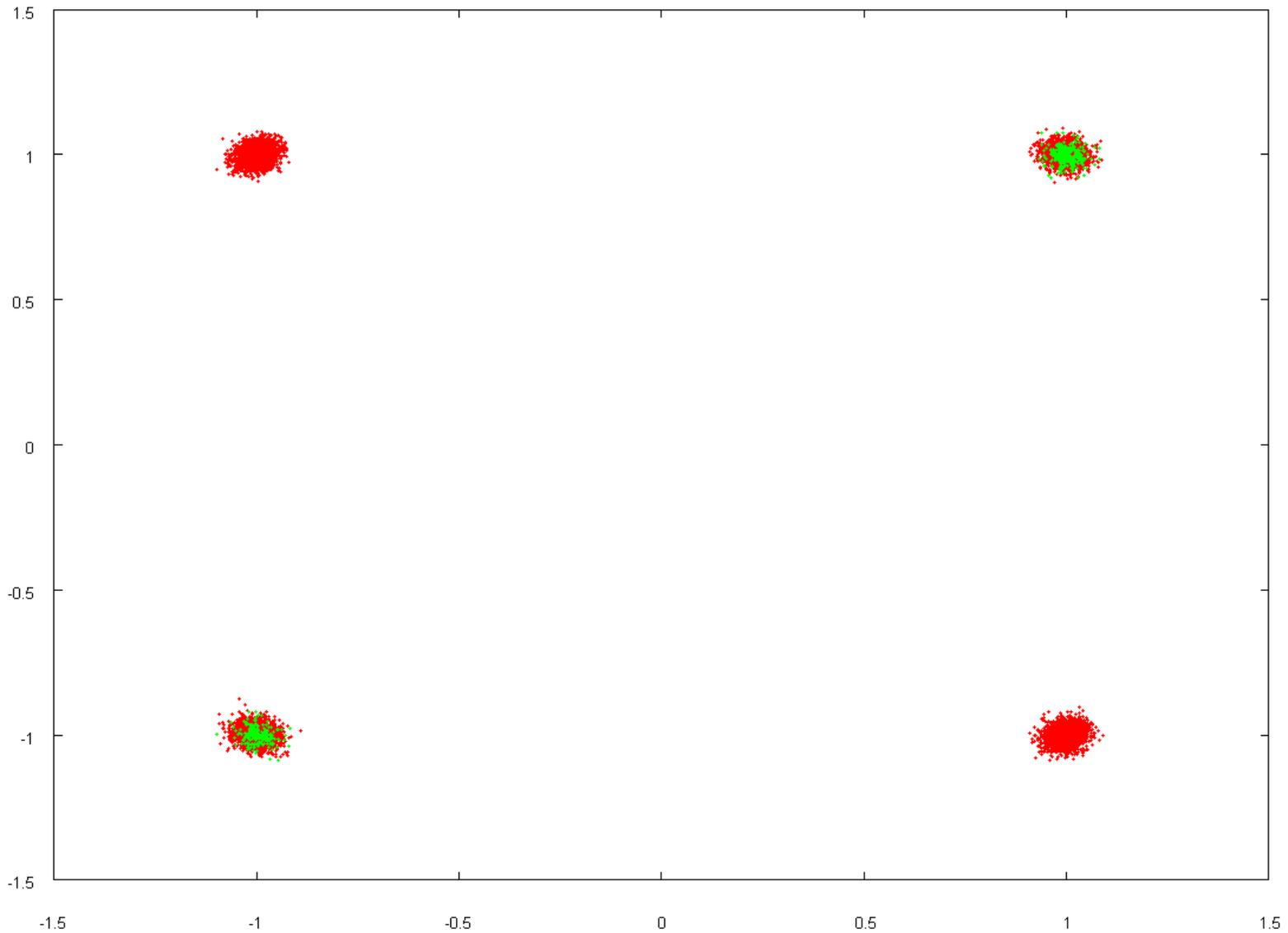
UNCORRECTED TRANSMITTER OUTPUT WITH PAR SUBTRACTED

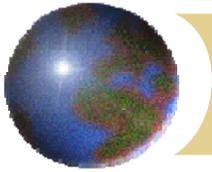




IBOC COFDM CONSTELLATION DISPLAY

CORRECTED TRANSMITTER OUTPUT WITH PAR SUBTRACTED

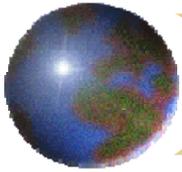




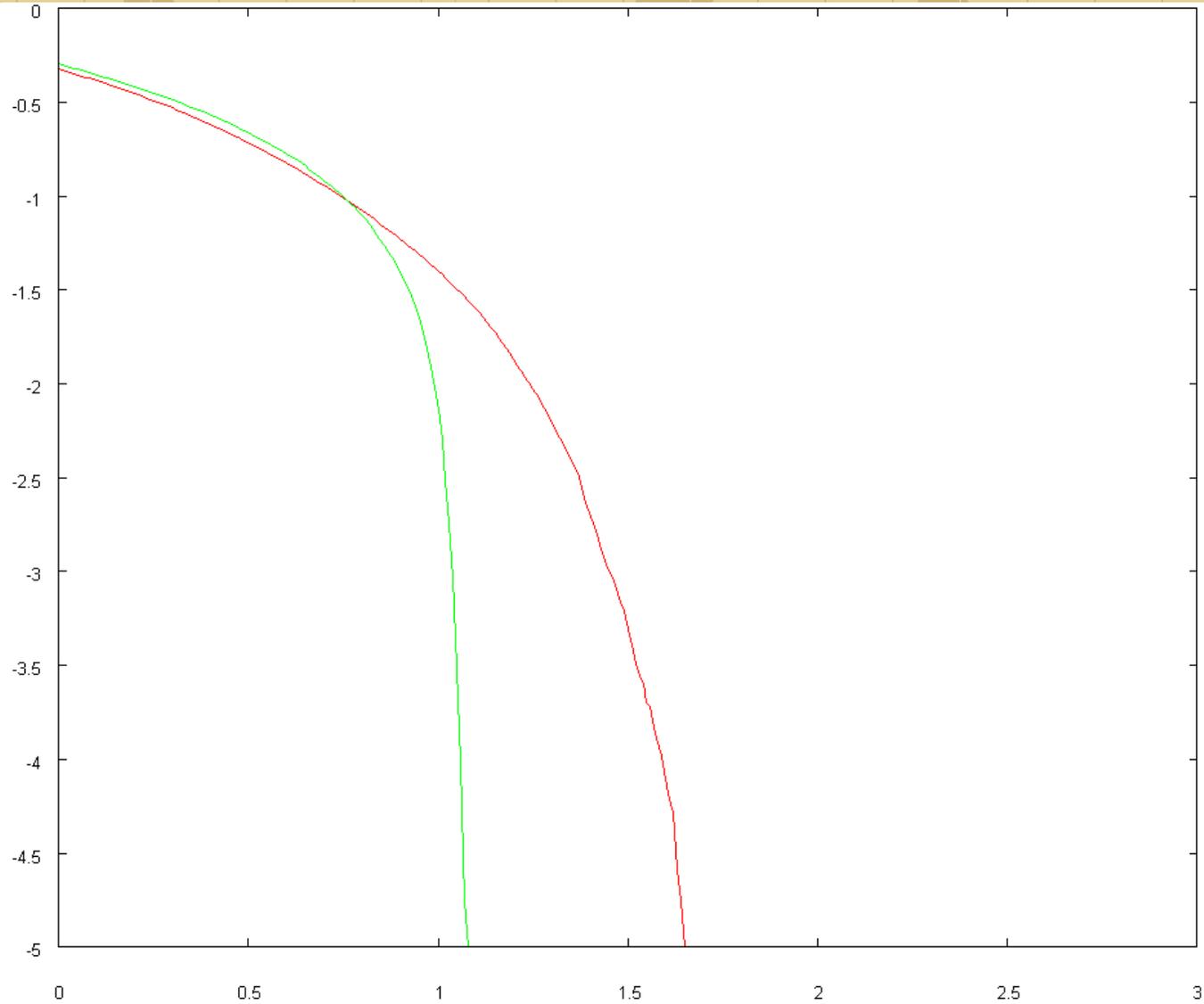
PERFORMANCE MEASUREMENTS

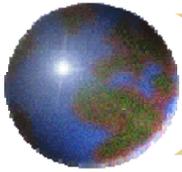
- **SPECTRUM AND MASK COMPLIANCE**
 - ▶ Spectrum analyzer
- **DIGITAL POWER LEVEL MEASUREMENT**
 - ▶ Frequency selective power measurement
- **ENVELOPE MODULATION**
 - ▶ “AM noise” due to linear addition of COFDM sidebands
- **PEAK TO AVERAGE RATIO**
 - ▶ Cumulative probability density function – shows clipping
- **ERROR VECTOR MAGNITUDE**
 - ▶ Measures linear and nonlinear distortions
- **CONSTELLATION DISPLAY**
 - ▶ Shows transmitted digital signal quality



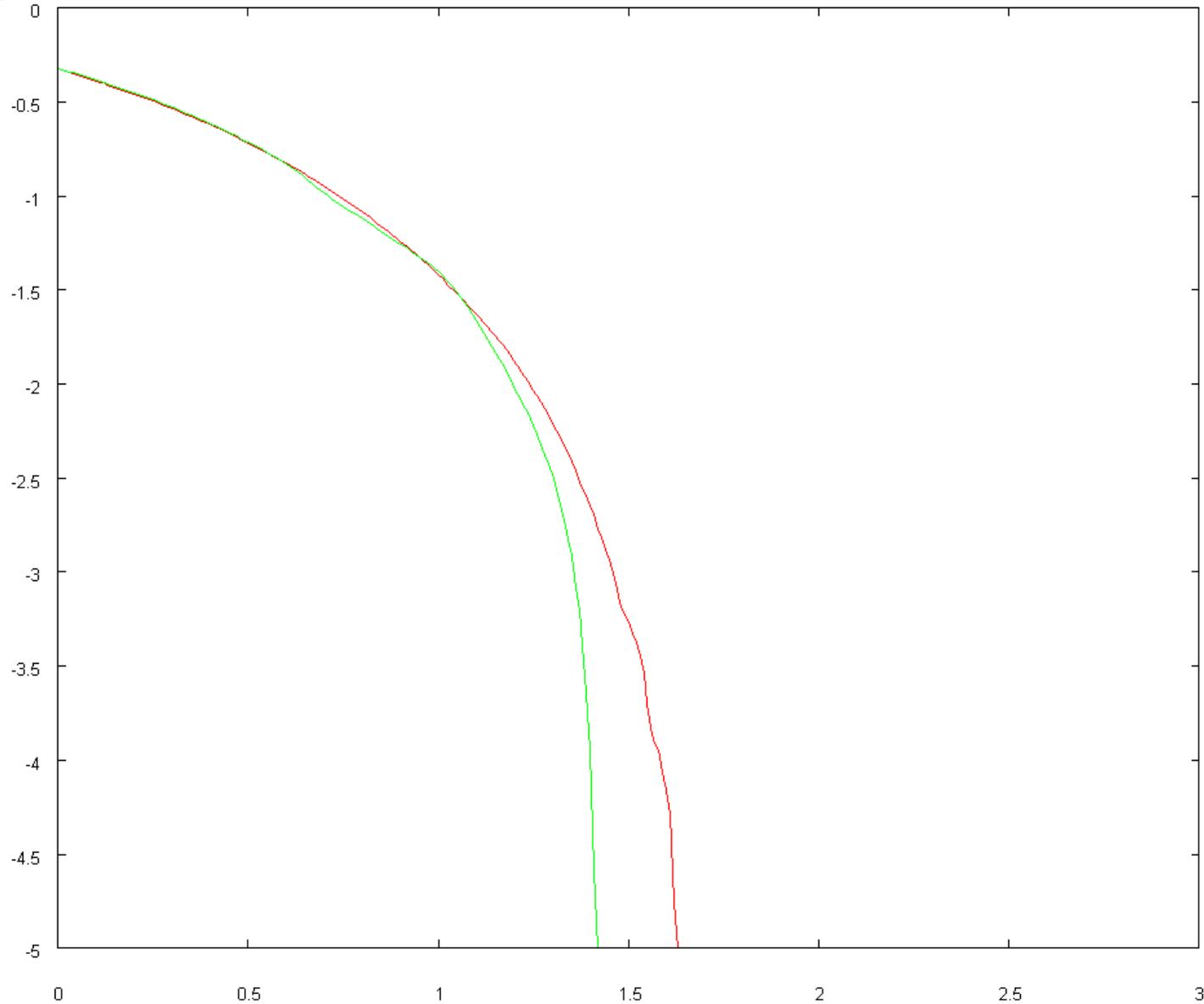


PEAK TO AVERAGE DISPLAY UNEQUALIZED TRANSMITTER

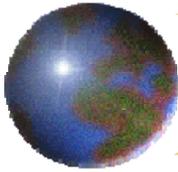




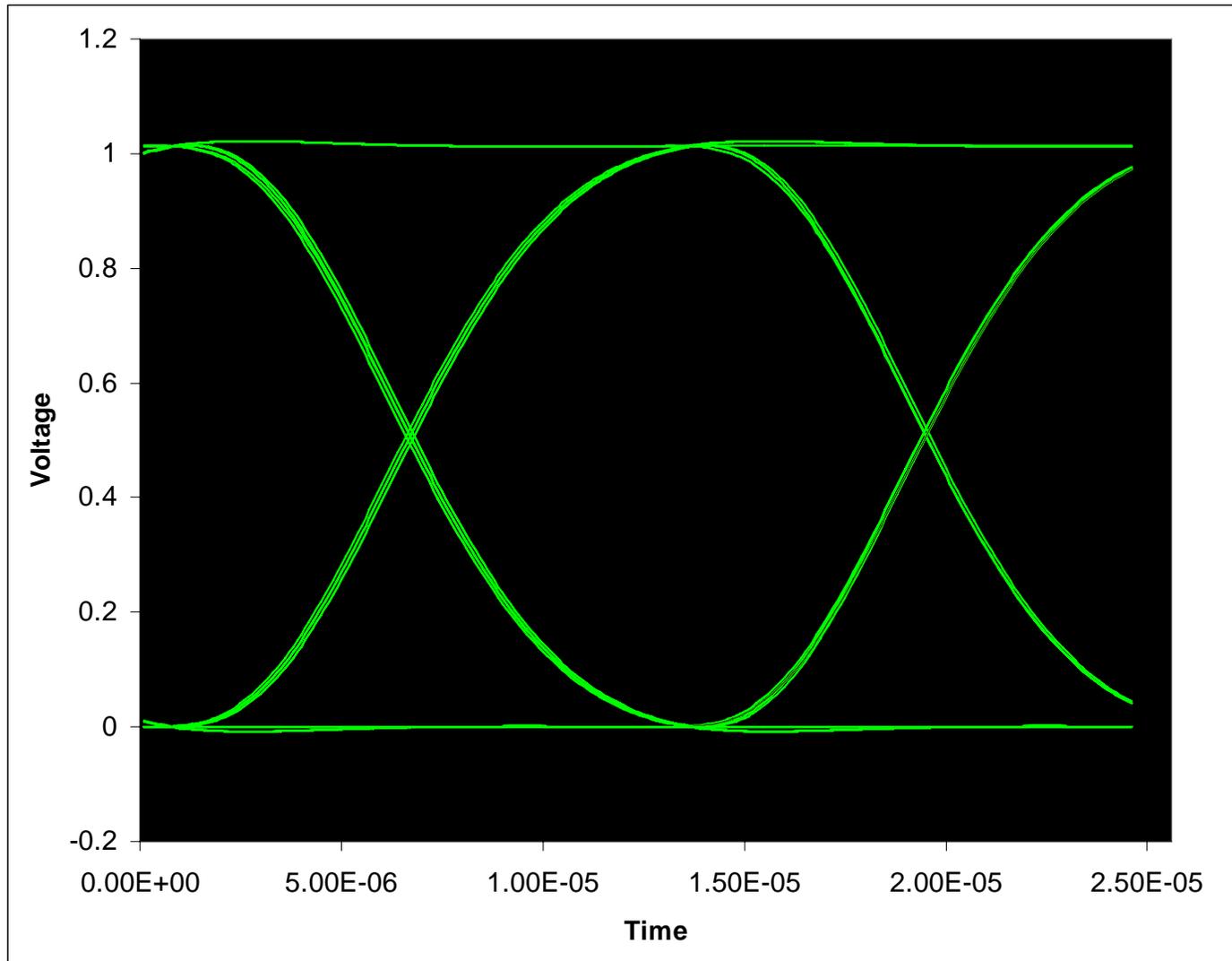
PEAK TO AVERAGE DISPLAY ADAPTIVELY EQUALIZED TRANSMITTER

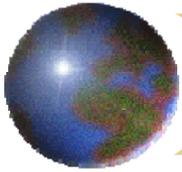


Broadcasters Clinic 2008

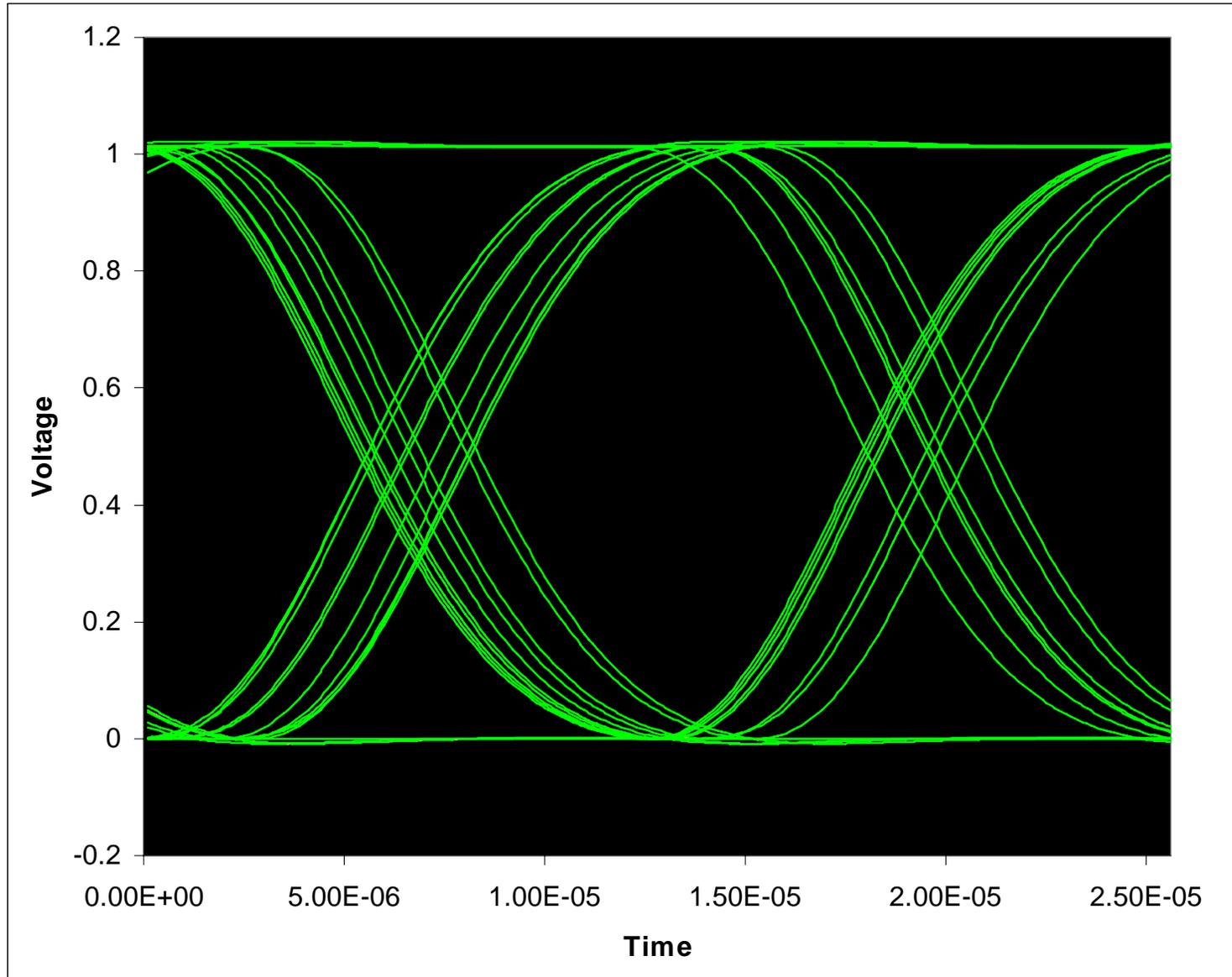


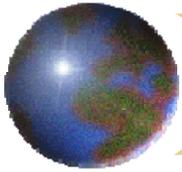
RADIO QUALITY DATA SIGNAL



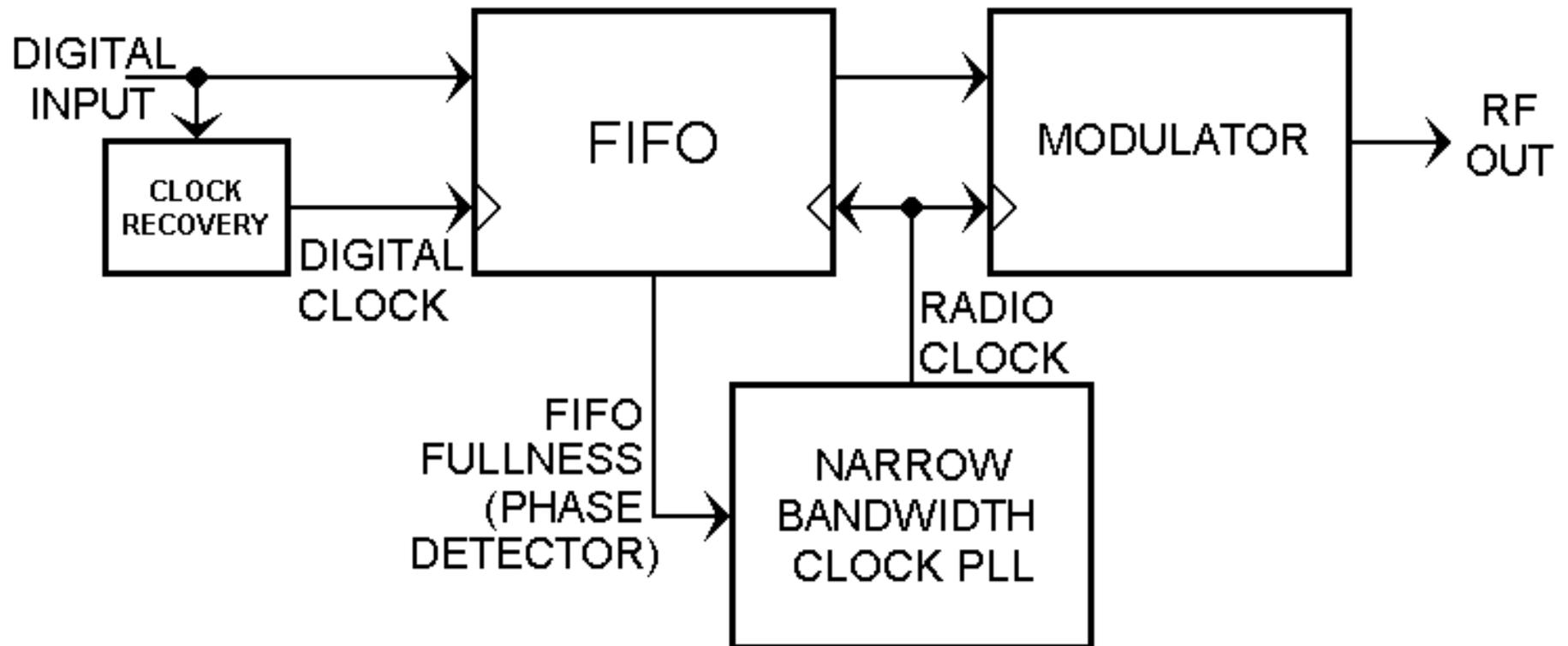


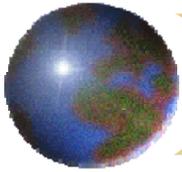
COMPUTER QUALITY DATA SIGNAL





RADIO QUALITY (ALMOST?) CLOCK RECOVERY FROM DATA QUALITY SIGNAL



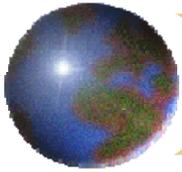


VARIABLE STL LATENCY

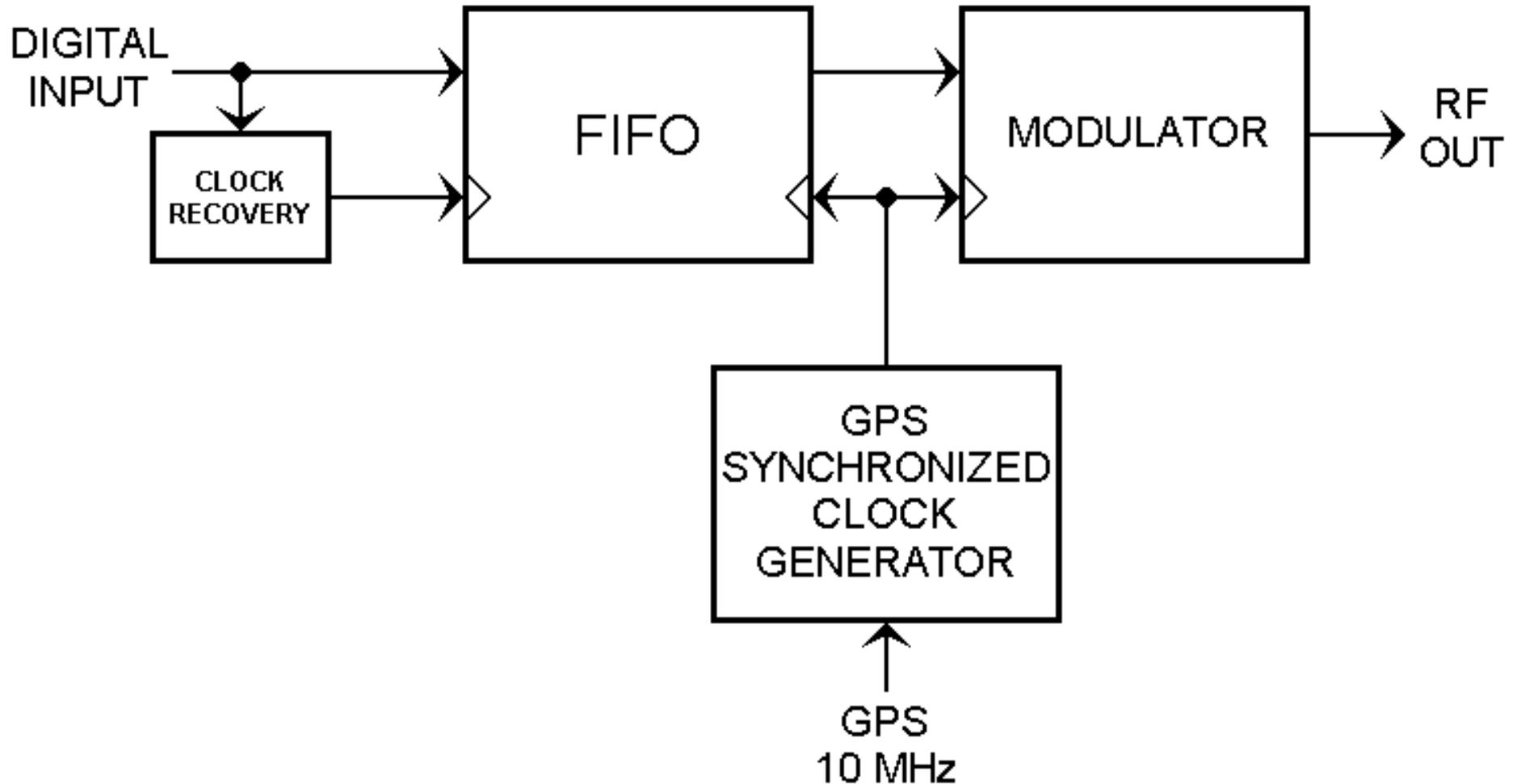


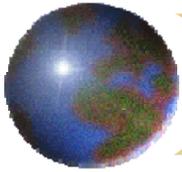
If your STL acts like a rubber band, there may be SFN timing problems!



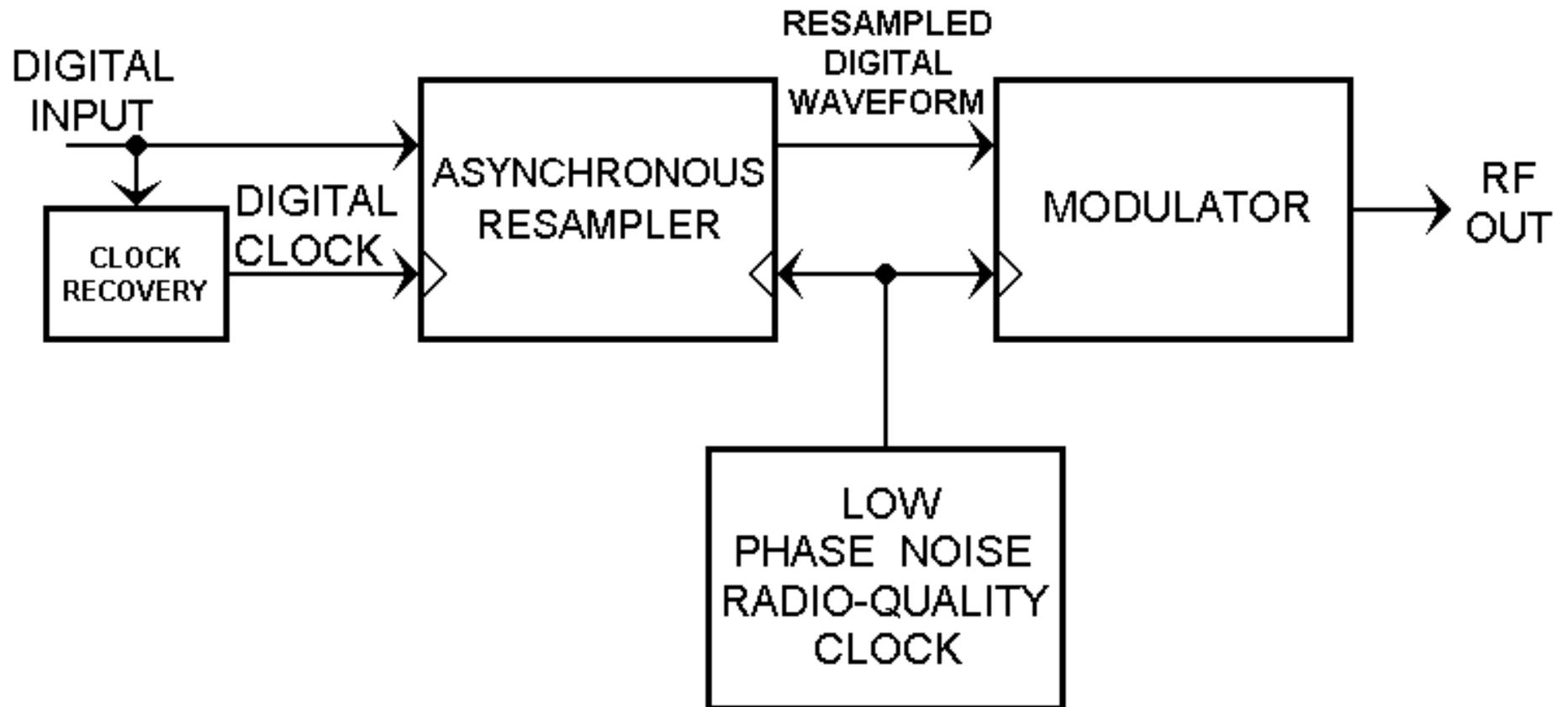


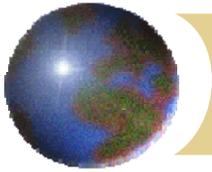
RADIO QUALITY CLOCKING FROM GPS (REQUIRES DATA SYNC TO GPS)



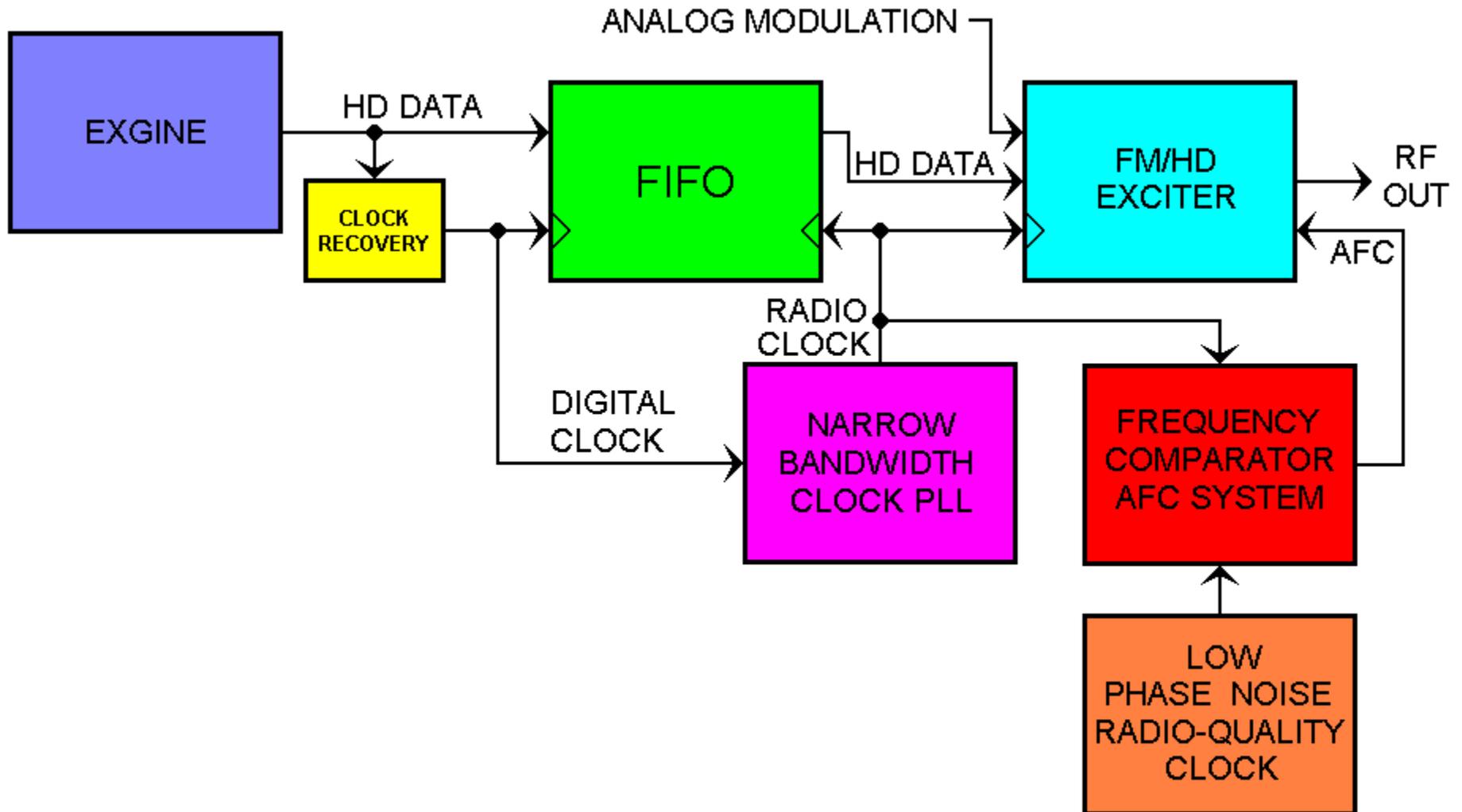


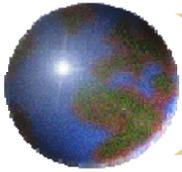
RADIO QUALITY CLOCKING BY ASYNCHRONOUS RESAMPLING



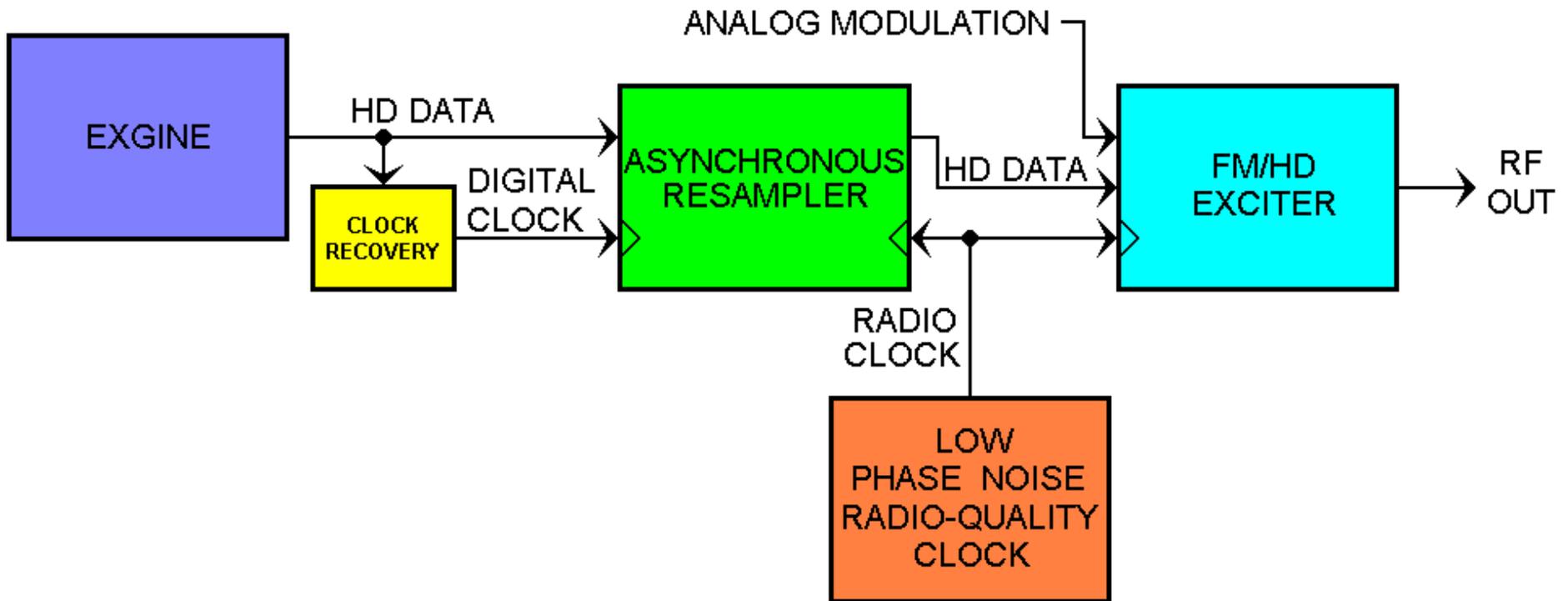


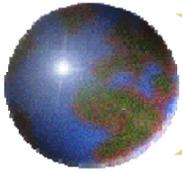
THE WRONG WAY TO CLOCK AN EXCITER



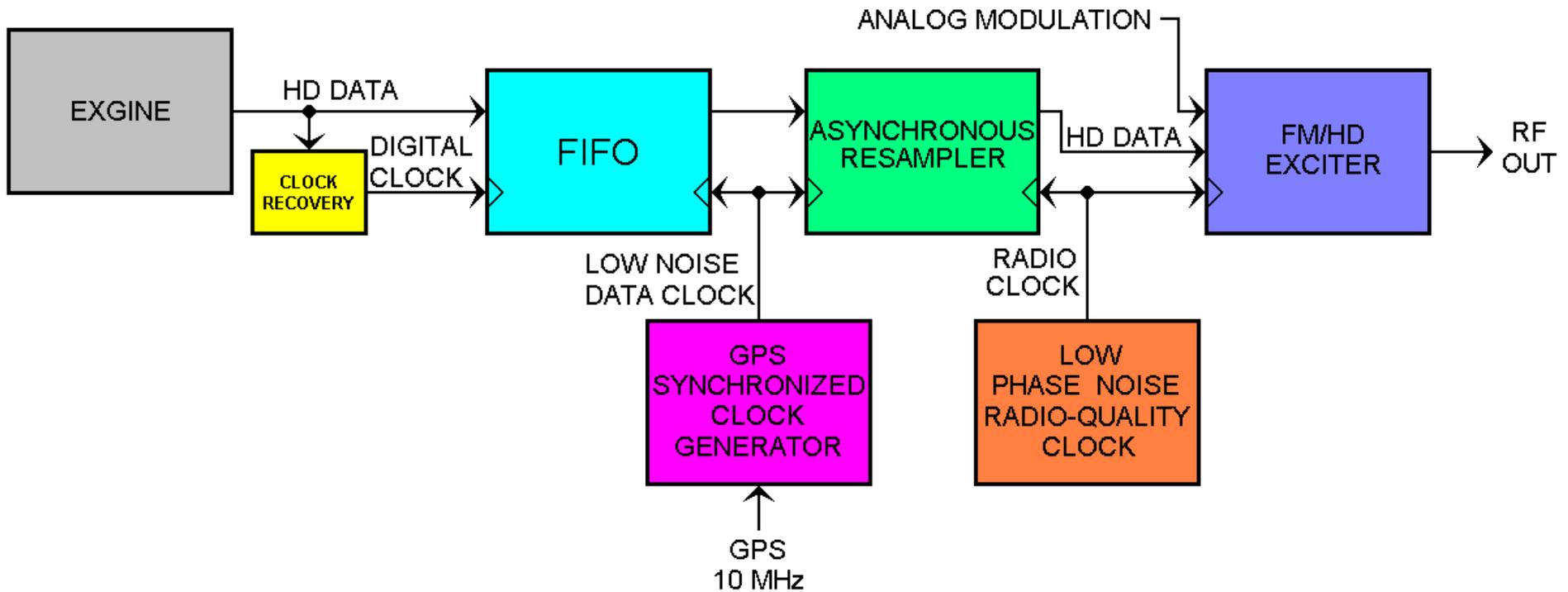


THE RIGHT WAY TO CLOCK – ASYNCHRONOUS RESAMPLING



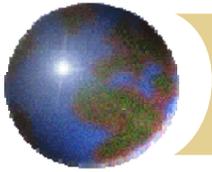


THE RIGHT WAY TO CLOCK WHEN IMPLEMENTING A SFN



GPS LOCKING AND ASYNCHRONOUS RESAMPLING COMBINED



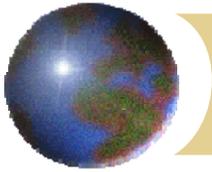


PROTECTING YOUR ANALOG SIGNAL

• DUAL INPUT/ANTENNA SYSTEM

- ▶ PAY ATTENTION TO TURNAROUND LOSS OF ANALOG TRANSMITTER
- ▶ MAY ELIMINATE NEED FOR HIGH POWER CIRCULATOR
- ▶ COMBINED TRANSMITTERS CAN HAVE EXCELLENT TURNAROUND LOSS IF INSTALLED CORRECTELY
- ▶ REDUCE MULTIPATH DURING HIGH VSWR (E.G. ICING)

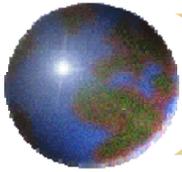




PROTECTING YOUR ANALOG SIGNAL

- **MASTER ANTENNA SYSTEMS**
- **USE EXISTING HD TRANSMITTER IN ANALOG ONLY MODE WITH GROUP DELAY CORRECTION**
 - ▶ GROUP DELAY CORRECTION REQUIRES ENVELOPE MODULATION AVAILABLE IN HD DESIGN
 - ▶ ALLOWS TRANSMITTER EFFICIENCY TO APPROACH STANDARD ANALOG PERFORMANCE WITH MUCH BETTER AUDIO PERFORMANCE
 - ▶ CAN CORRECT VERY LARGE COMBINER GROUP DELAY DISTORTIONS
 - ▶ ALLOW MORE STATIONS TO COMBINE WITH CLOSER CHANNEL SPACINGS

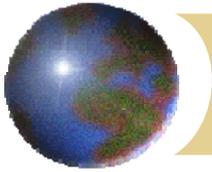




CONCLUSION

- **EMBEDDED EXPORTERS**
- **TRANSMITTER TOPOLOGIES**
- **UPGRADE PATHS**
- **POWER INCREASE CONSEQUENCES and SFNs**
- **ADAPTIVE EQUALIZATION**
- **BUILT-IN TEST EQUIPMENT FUNCTIONS**
- **KEEPING COMPUTER CLOCK JITTER OFF THE AIR**
- **PROTECTING YOUR ANALOG SIGNAL**





Thank You!

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