Digital Radio Frequency Memory Technology & Techniques for EW

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Overview of Presentation

- INTRODUCTION
- History of DRFMs
- Digital RF Memory Architectures
- Technology Trends
- Applications of DRFMs
- Summary and Conclusions
The DRFM – History (1)

Earliest Reference to the DRFM

“A Coherent Microwave Memory Using Digital Storage: The Loopless Memory Loop”
by Sheldon C. Spector,
Electronic Defense, 1975
The 1980’s Threat – **Pulse Compression Radars**

Animation - Courtesy of the CSIR, Pretoria, South Africa
**Pulse Compression Radar Advantage**

- Signal Processing Gain (SPG) of the pulse compression radar (typically 20-30 dB)

- Only ‘real’ targets processed with the SPG

- Noise jamming ineffective because non-coherent signal and insufficient power to account for SPG
First DRFM EW Application –
Electronic Countermeasures (ECM) Suite

*Airborne Self Protection Jammer (ASPJ) ALQ-165 started development in 1979 but was cancelled in 1992 for a variety of political and operational reasons*
3-bit Phase DRFM Architecture (1980’s)

400 MHz bandwidth obtained by phase sampling and phase-to-digital converters
The DRFM – History (6)

The Solution to Pulse Compression Radar Problem

- The instantaneous bandwidth of the DRFM was in excess of the radar bandwidth ✓

- The DRFM fidelity was good enough for the radar to process generated targets as real targets ✓

- The radar processing gain affected both real and false targets ✓
DRFM Architecture Types

- Phase Encoding
- Amplitude Encoding
- I-Q Encoding
Physical Architectures

Phase Encoding DRFM

I - Channel

90

Q - Channel

From RF

To RF
Amplitude Encoding DRFM
Quadrature (I-Q) Encoding DRFM

Control

X

A/D

Memory

D/A

X

+ 

To RF

90

I - Channel

From RF

Q - Channel
Encoding Signal Constellations

Amplitude

Phase

Quadrature
Basic Properties (1)

- **Phase DRFM**
  - High Bandwidth
  - Encoding complications
  - No multiple signals
  - No amplitude information

![Diagram of DRFM response]

- **DRFM response**

![Graph showing encoded amplitude vs. frequency]

- **Encoded Amplitude**
  - $0$ $f_s$
  - $0$ $T$

- **Amplitude**
  - $0$
  - $T$

- **Frequency**
  - $-\frac{f_s}{2}$
  - $0$
  - $\frac{f_s}{2}$
Basic Properties (2)

- **Amplitude DRFM**
  - **Good Bandwidth**
  - **Simple COTS Encoding**
  - **Multiple signals capabilities**
  - **Difficulties with phase**

![Graph showing DRFM response and encoded amplitude over frequency](image)
- Quadrature DRFM
  - High Bandwidth
  - COTS Encoding
  - Difficult to directly control phase on data
  - Most expensive
**Original Amplitude DRFM Structure**

- **Discrete processing functions (1990’s)**
  - Control
  - A/D converter
  - Memory
  - D/A converter
  - Doppler modulator
- **Bandwidths up to 500 MHz**
• “The number of transistors per square inch on an integrated circuit will double every 18 months”

• This results in a subsequent increase in processing power (speed)
DRFM Bandwidth Trends

Maximum Bandwidth (MHz)

- 1000
- 750
- 500
- 250

Ampl & Phase
Ampl

1988 1998 2008 2018

Bandwidth Primarily Determined by A/D & D/A Technologies

COTS Technology Is Prime Trend Driver

Ampl

Ampl & Phase

Ampl
Modern Amplitude DRFM Structure

- FPGA Implementation in all digital sections
- Bandwidths ≥1.5 GHz
DRFM Applications in EW

- Tactical Electronic Countermeasures
- Radar Test and Evaluation
- ECM Simulators
- EW Training
DRFM Advantage

- DRFM receives and transmits the same pulse and the radar receives its pulse compression signal.
- DRFM advantage is that the deception pulses have the same signal processing gain (SPG) of the radar:
  - Decrease required ERP for an EA system.
DRFM Fidelity in ECM

INPUT SIGNAL

45 MHz CHIRP INPUT TO DRFM FREQUENCY DOMAIN

GENERATED 45 MHz CHIRP AFTER PULSE COMPRESSION FILTER TIME DOMAIN

OUTPUT SIGNAL

REPLAYED 45 MHz CHIRP FREQUENCY DOMAIN

REPLAYED 45 MHz CHIRP AFTER PULSE COMPRESSION FILTER TIME DOMAIN
DRFM based ECM Techniques Against Acquisition Radars

- **Multiple Targets**
  - Confuse and deceive

- **Range Gate Pull-Off**
  - Stop acquisition

- **Inverse Gain**
  - Deny angular information

- **Bin Masking**
  - Deny range and velocity tracking
Multiple Single Targets

False Targets

Input Pulse

Lead target delay

Associated target delays

Output Pulses
Multiple False Targets

*Saturate the Radar with Multiple False Targets*
Multiple Groups of Targets

- Input Pulse
- False Targets
- Lead target delays
- Lead target
- Motion of target groups
- Output Pulses

EW Asia
Multiple Groups of Targets

Saturate Radar Display with False Information
Inverse Gain – Denying Target Bearing

Amplitude is inverted on each output pulse
Inverse Gain – Denying Target Bearing
DRFM Generated Noise

- Synthesise noise using the DRFM memory in ‘memory write’ mode
- Match the noise to the radar bandwidth using DRFM receiver
- Burst, continuous and spot noise generation
DRFM Generated Burst Noise
DRFM Generated Noise
Noise Sector Jamming
DRFM Generated Noise
Saturation Noise Jamming
ECM Simulators Using DRFMs

- Applications include hardware-in-the-loop (HIL) systems, ECM training and ECM techniques development
- Specific feature is system programmability – similar in capability to Radar Threat Simulators
- Full easy-to-use GUI implementation
ECM Simulator Architecture

- RF FRONT END (Down Convert)
- LOCAL OSC
- DRFMS
- UP CONVERT
- TECHNIQUES CONTROLLER

1-18 GHz
DRFMs can be used to test radar performance

Test Systems (Radar Target Generators) are fully programmable in terms of target RCS & target movements using scenario generators
Early days of target generation and ECM

- Target generator provides a range delay ($\Delta T$) and echo return amplitude
- Received pulsewidth = transmitted pulsewidth
- Effective against simple types of radars
- 1-D targets
Modern day requirements for target generation and ECM

- Target generator provides a range delay (ΔT) and echo return amplitude (RCS) vs time (= range extent targets)
- Received pulsewidth ≥ transmitted pulsewidth
- Targets are 3-D with different RCS depending on aspect angle (Az & El)
- Effective against most modern types of radars
• Complex target properties create complex RCS
• Multiple scattering points and surfaces
• Scattering points provide both amplitude and phase reflections
“Delay Line” FPGA design approach
Multiple scattering points for complex targets
3-D target generation capability in real time
Comparison of Original RCS Data and Synthesised RCS Data
DRFMs in ECM Training

- To train radar operators on actual equipment
- To improve operator skills particularly in ECCM
- To provide real-world situations to assess performance
- To provide tactics training
- To evaluate system performance
Dual Channel ECM Simulators

- Dual parallel DRFM channels allows the creation of a simulated target (missile) and self screening jamming techniques at the same time
- Can create a target for a radar operator and then self screen ECM
Anti Ship Missile EW Training

- Used by many Navies worldwide
- Many private contractors providing this service to military
- DRFMs provide sophisticated ECM against all modern (and legacy) radars
- Programmability of ECM simulators in this application gives maximum flexibility in use and future upgrade
DRFM Usage in ASM Training

Generate on-board jamming

Generate missile target to ship radar

Generate missile radar signal switch on

Ship radar transmits

Can be accomplished with 2 DRFMS
Airborne Implementation

Flight International’s SMART CROW™ Plus with the EWsT Chameleon RADER Jammer On Station Down Under – Exercise Tandem Thrust
Summary and Conclusions

- DRFMs are an important and integral part of EW technology and for ECM systems
- DRFMs enable very complex radar testing and evaluation
- DRFM technology has benefited from COTS components resulting in significant performance improvements over the past 10 years
- Trend is for more applications to become available as technology continues to improve and prices decrease
Questions?

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