

Direct Antenna Modulation: Analysis, Design, and Experiment

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Overview

1. Motivation

- Application to Army comm. systems

2. Direct Antenna Modulation (DAM)

- Potential benefits
- General concept

3. DAM Experiment

- Experiment details
- HFSS simulations
- Construction and testing

4. Conclusion

- Recap of completed research and experimentation
- Future research plans

Motivation

- 80% of Army ground mobile communications occurs in the HF - UHF bands
 - Low frequency: 3 MHz – 1 GHz
 - Long wavelength: 30 cm – 100 m



M577A3 Tracked Command Post Carrier [sill-www.army.mil](http://www.army.mil)



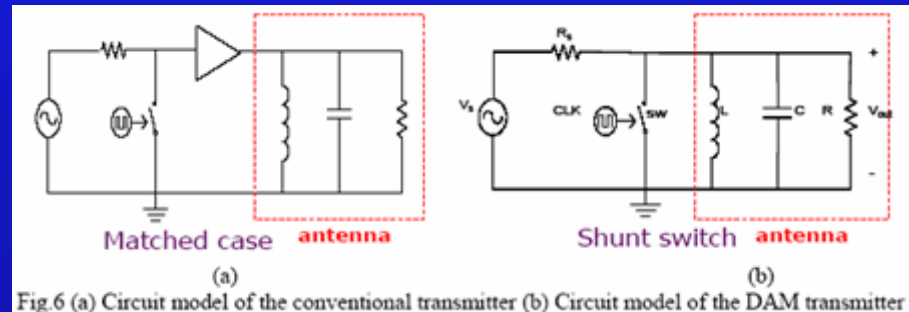
Manpack Radio Set AN/PSC-3
www.tobyhanna.army.mil

Typical antenna designs yield:

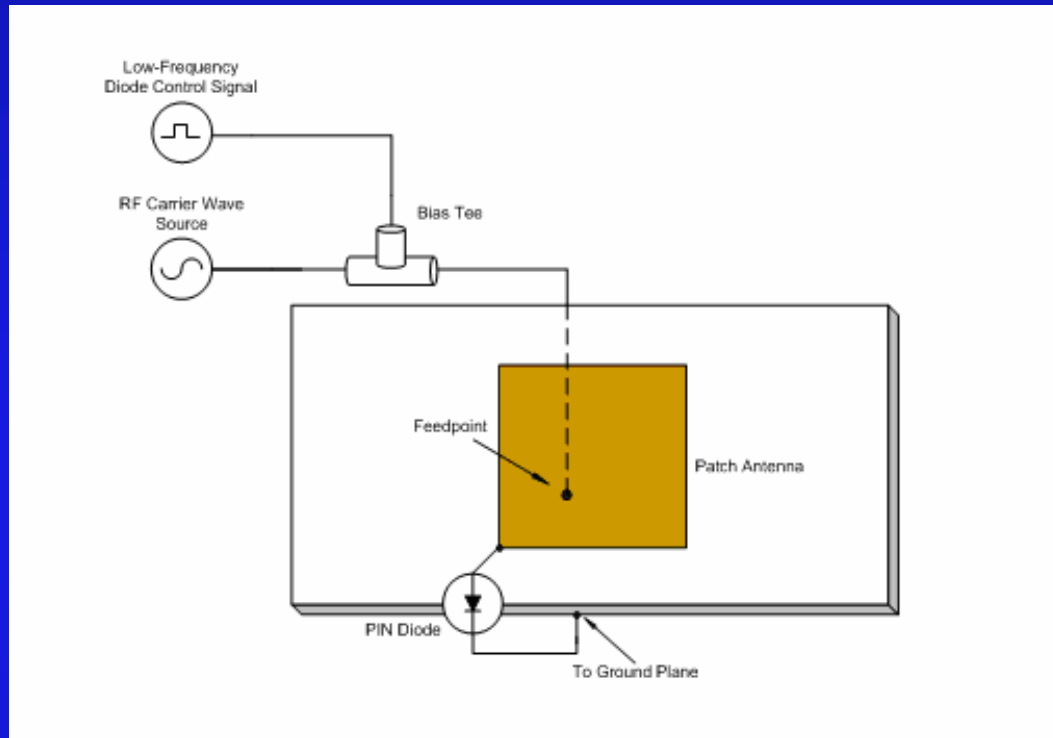
- *Cumbersome size*
- *Visually-compromising signature*

Novel Concept in Antenna Design

- Antennas typically are designed to operate at resonance
 - Resonant matching network to the transmit/receive circuitry for maximum power transfer
 - Inherently narrowband system
- Antenna operation in linear but non-resonant modes gives increased bandwidth at the cost of greatly reduced efficiency
- Direct antenna modulation (DAM) uses techniques developed for high-efficiency switching amplifiers to decouple the information bandwidth from the antenna resonance
 - Switching diode operates in saturation not in linear mode
 - May enable efficient operation over extremely wide bandwidths with electrically small antennas



DAM General Concept

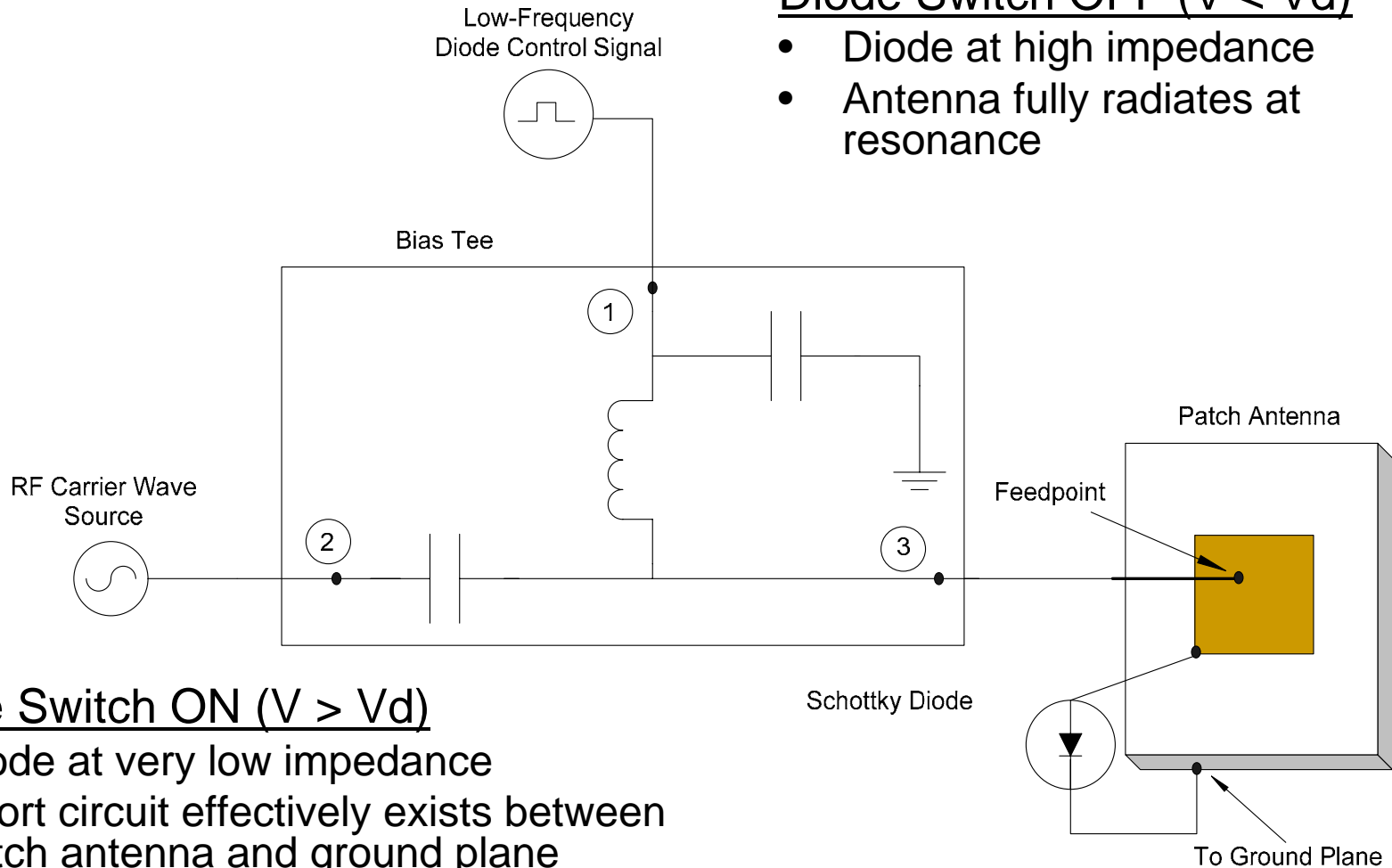


1. Fast-switching diode (e.g. Schottky or PIN) connected between antenna and ground plane
2. External carrier wave passes through bias tee and drives antenna at resonance
3. Baseband information signal passes through bias tee to feedpoint and controls diode switching
4. Diode switching directly controls antenna radiation, resulting in a modulated carrier wave signal

Direct Antenna Modulation

Diode Switch OFF ($V < V_d$)

- Diode at high impedance
- Antenna fully radiates at resonance



Diode Switch ON ($V > V_d$)

- Diode at very low impedance
- Short circuit effectively exists between patch antenna and ground plane
- Oscillating charges on antenna radiation slots flow through diode to ground plane
- Antenna radiation effectively ceases

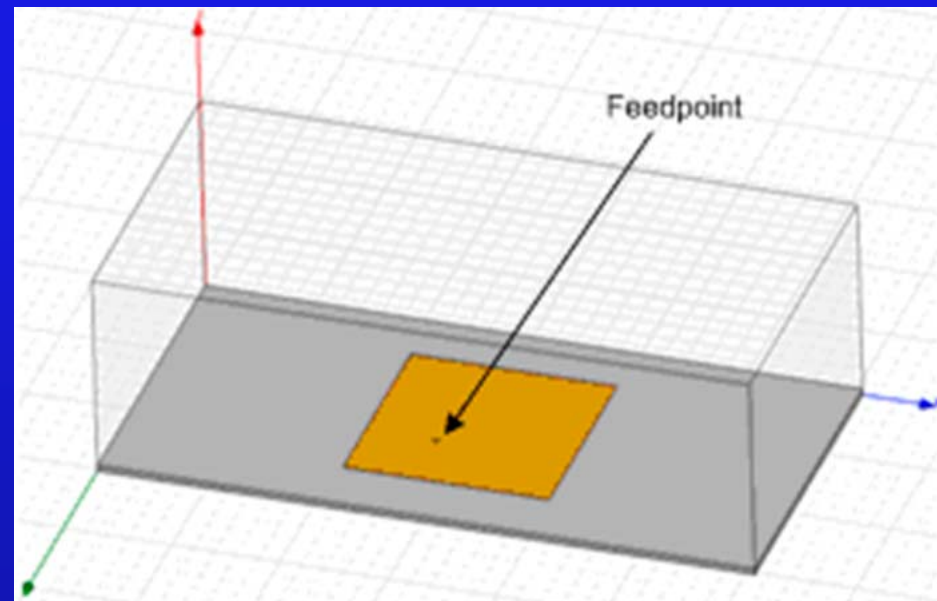
DAM Experiment

Objectives:

- Verify the feasibility of the direct antenna modulation technique with an L-band patch antenna
- Observe the upper limit to information bandwidth and compare to that of a basic amplitude-modulated system, limited by its resonant antenna bandwidth

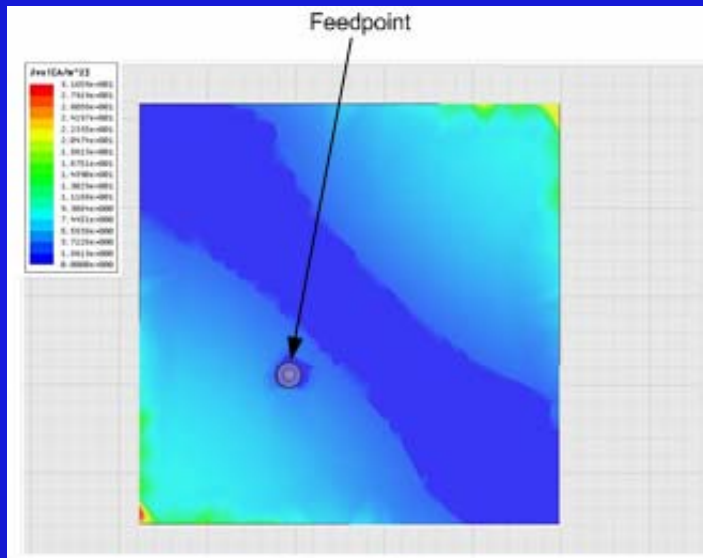
Antenna:

- Symmetric L-band patch
- $f_r = 1.5$ GHz
- Coaxial feed
- G-10 epoxy glass substrate, $\epsilon_r \sim 4.24$
- ~15 to 20 MHz Bandwidth (narrowband)
- Modeled using *Ansoft* HFSS

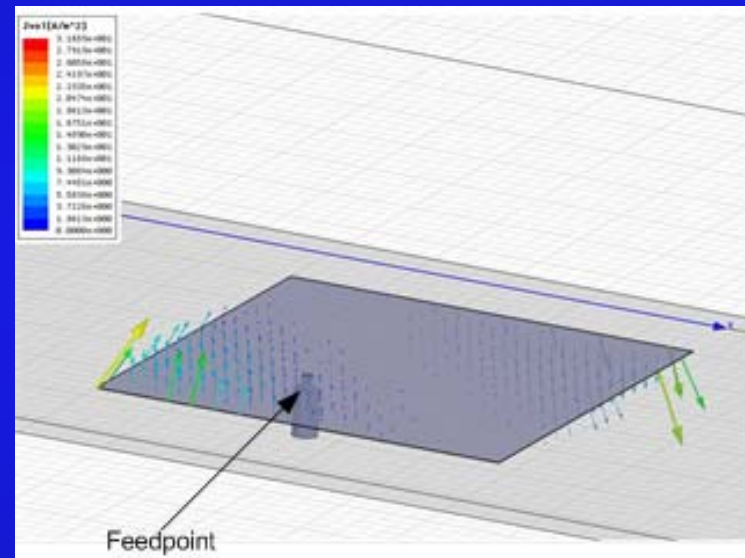


Use HFSS To Optimize Diode Placement

- Maximum volume current density points occur at the corners along the feedpoint diagonal



J_{vol} Magnitude Plot
(Bottom View of Patch Antenna)



J_{vol} Vector Plot
(Angled Top View of Patch Antenna)

- Diodes should be placed at these points for maximum effect on radiated signal

Diode Characteristics Are Critical

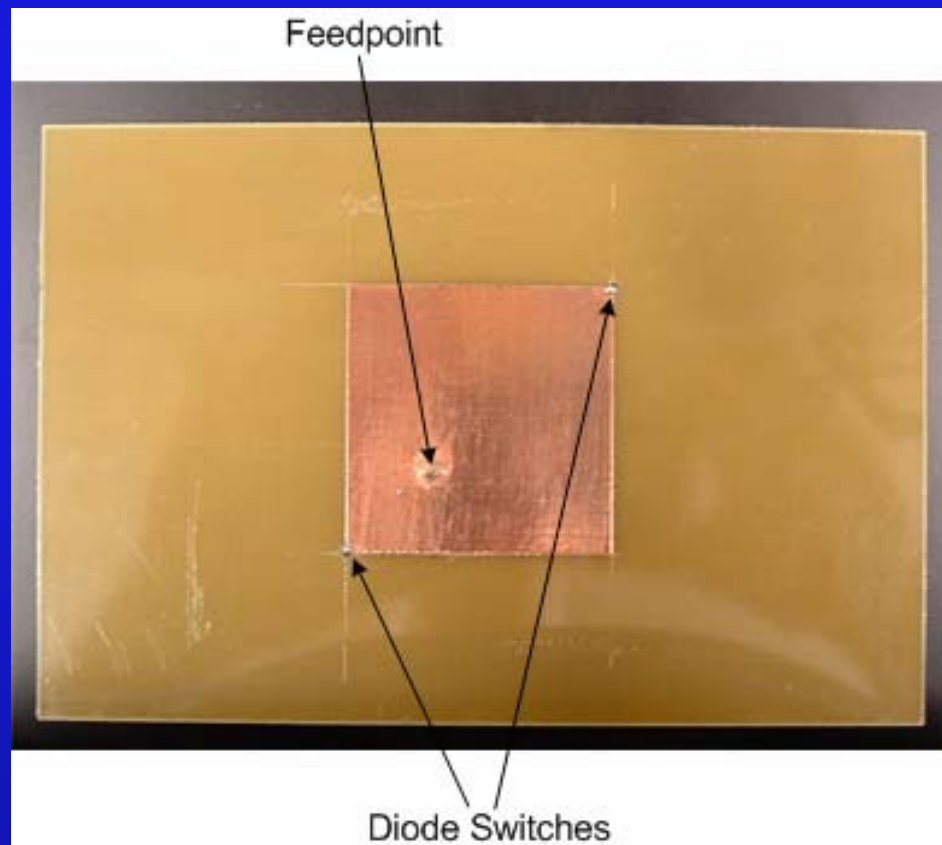
- SMP1340 (*Skyworks Solutions*) has low junction capacitance (0.3pF) at 0V forward bias
 - Looks like an open circuit at 1.5GHz

$$Z = \frac{1}{j\omega C} = \frac{1}{j \cdot 2\pi \cdot 1.5 \cdot 10^9 \cdot 0.3 \text{ pF}} = j354\Omega$$

- The SMP1340 is also a very fast-switching PIN diode (short carrier lifetime of ~100ns) which enables high modulation rates

Prototype Antenna

- Diodes soldered between patch antenna and ground
 - Located at the corners along the feedpoint diagonal



Signal Flow

Signal Generator



RF Signal

Function Generator



Diode Bias Control Signal

Bias Tee
Circuit



Bias Tee Output

Digitizing Signal
Analyzer



Received
Signal



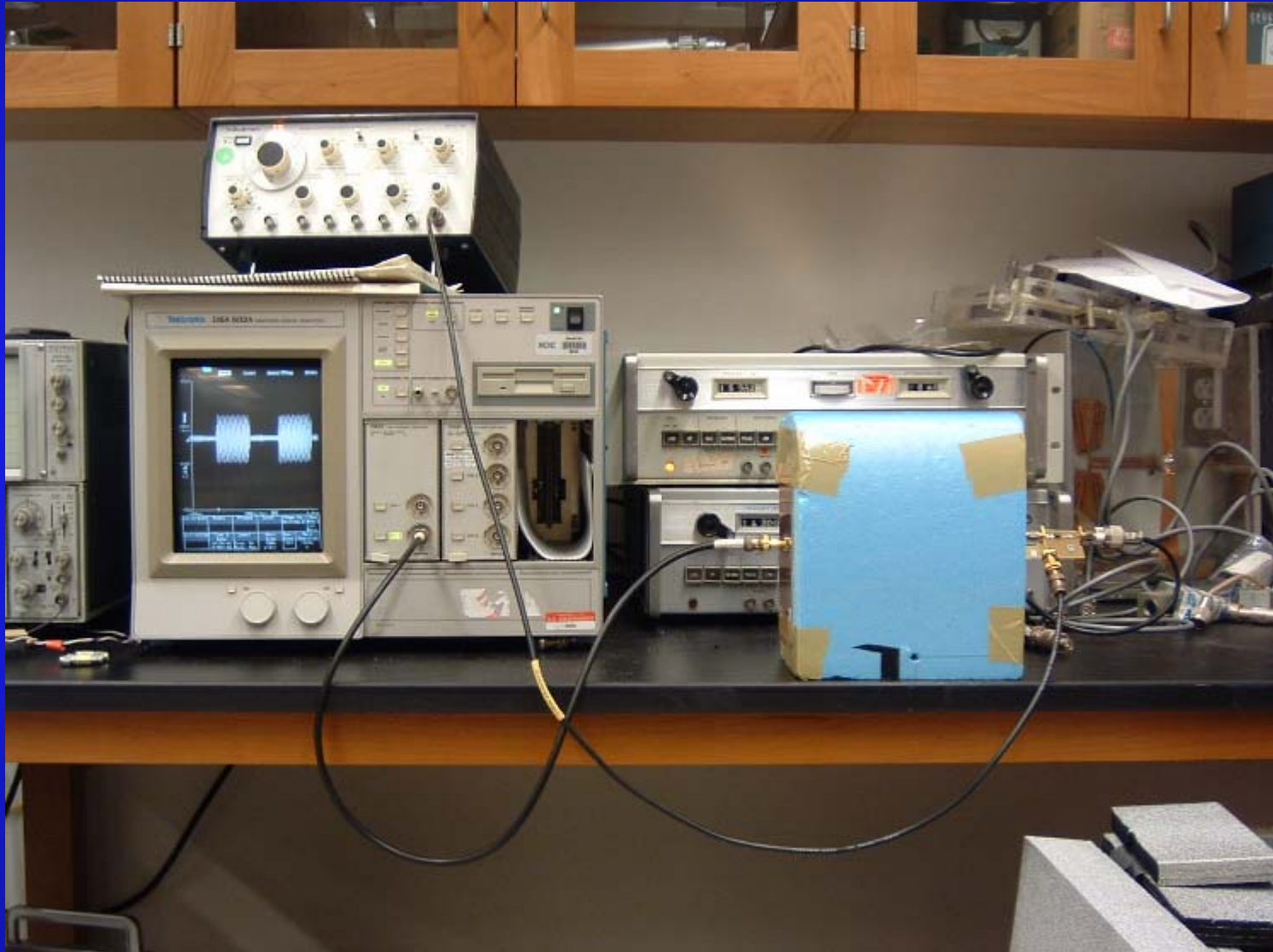
T

Transmitted
Signal



R

Experimental Setup



Modulation Results

- Received waveform demonstrates direct antenna modulation effect



10 kHz



1 MHz



10 MHz

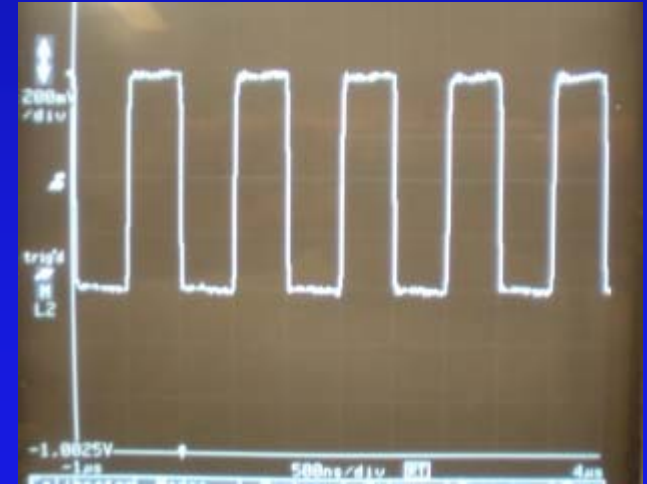
Well I'll be DAMed...it works!

Received Signal Details

Received Modulated CW:

~ 40 mV peak-to-peak

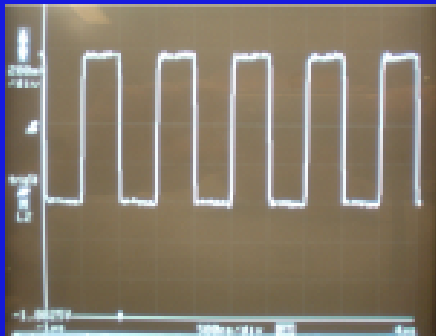
- Since diode has low, but not zero impedance when in forward bias, ~5mV received signal leakage occurs
- This leakage is minimal, however, yielding a signal peak to trough ratio of ~ 8:1



Function Generator Limits Performance

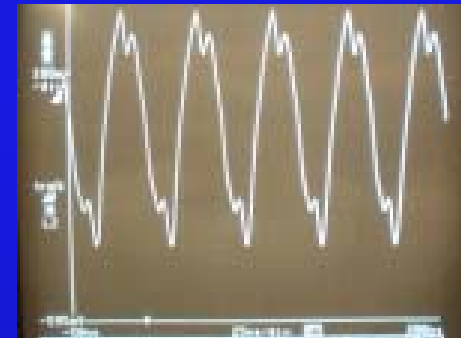
- Above 10 MHz, received waveform is distorted by degradation in the function generator bias signal

1 MHz

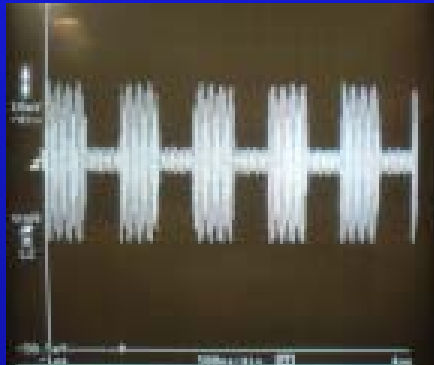


Bias
Signal

20 MHz



Received
Waveform



Conclusions and Future Work

- Direct Antenna Modulation is an effective technique for pulse modulation of radiation from a patch antenna
 - Diode selection and placement is critical
 - Fast switching speed, low junction capacitance
 - Placed at field strength maxima on the antenna for strongest effect
 - Bandwidth of modulation signal generator is important
-
- Develop computational and potentially nonlinear circuit models to analyze and predict direct antenna modulation performance
 - Extend technique to lower frequencies (HF – UHF) and test applicability to Army mobile ground comm. systems

References

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Questions?

