Lesson Title:
RFID Modulation, Encoding, and Data Rates

Dale R. Thompson
Computer Science and Computer Engineering Dept.

University of Arkansas

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Question

- If you have a signal at a particular frequency that passes through a particular media well, how do you convey information using that signal?

Modulation

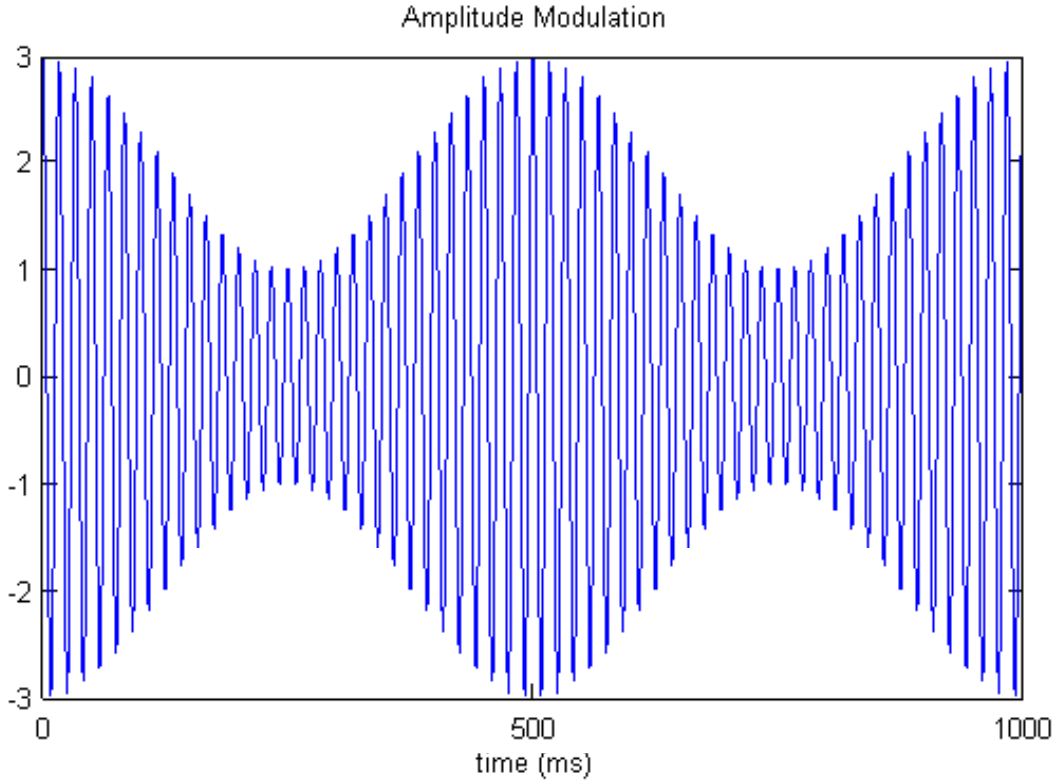
- Modulation is the process of modifying the characteristics of a signal, called a carrier wave, to convey information. The characteristics of a signal to modify include amplitude, frequency, and phase.

Analog modulation

- Analog baseband information to send and analog carrier wave

Amplitude modulation

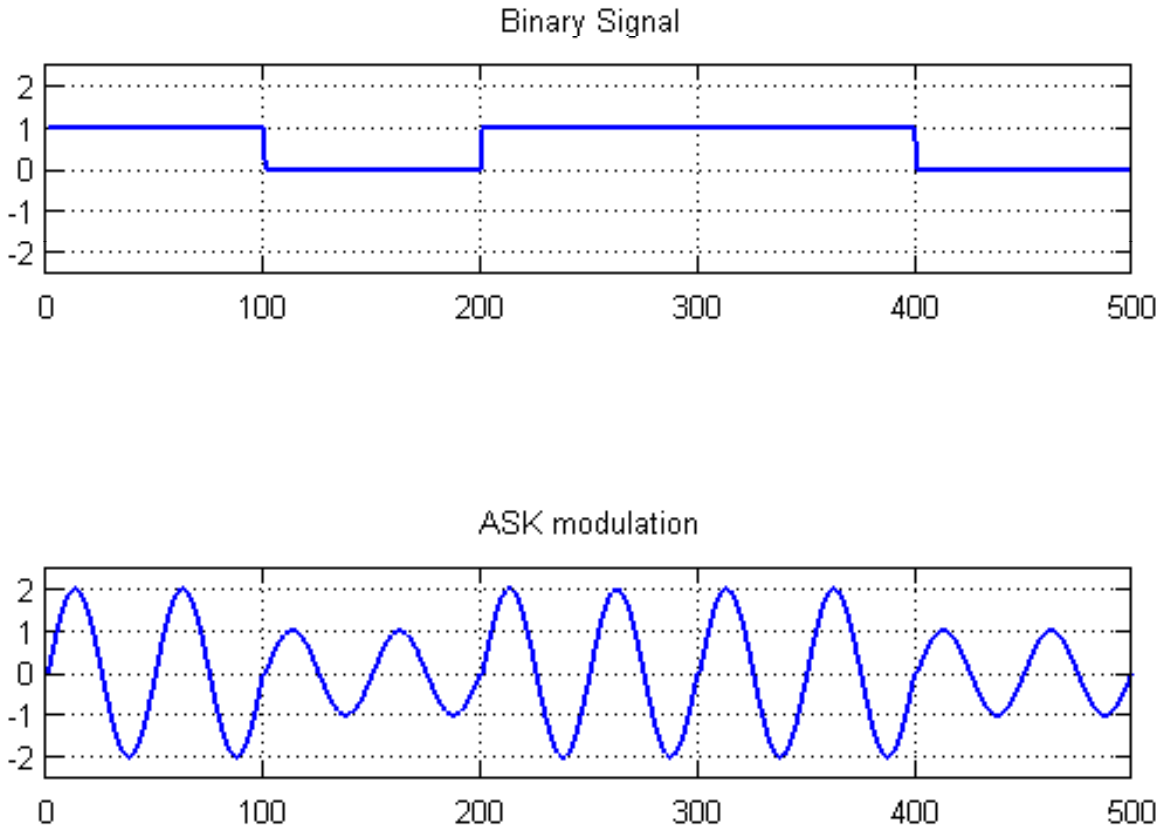
- x(t) = cos(2*pi*f1*t+2)*cos(2*pi*f2*t), f1 = 10 Hz, f2=100 Hz
- f1 = signal to convey; f2 = carrier wave; f1 < f2



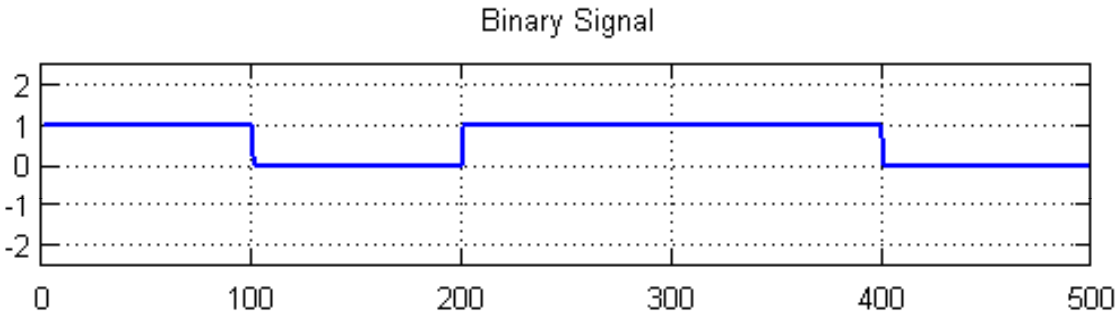
Digital modulation

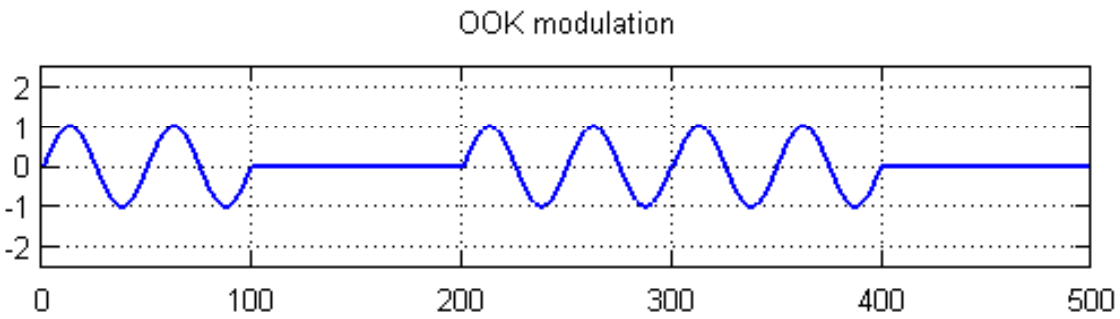
- Digital baseband and analog carrier

Amplitude-Shift Keying (ASK)

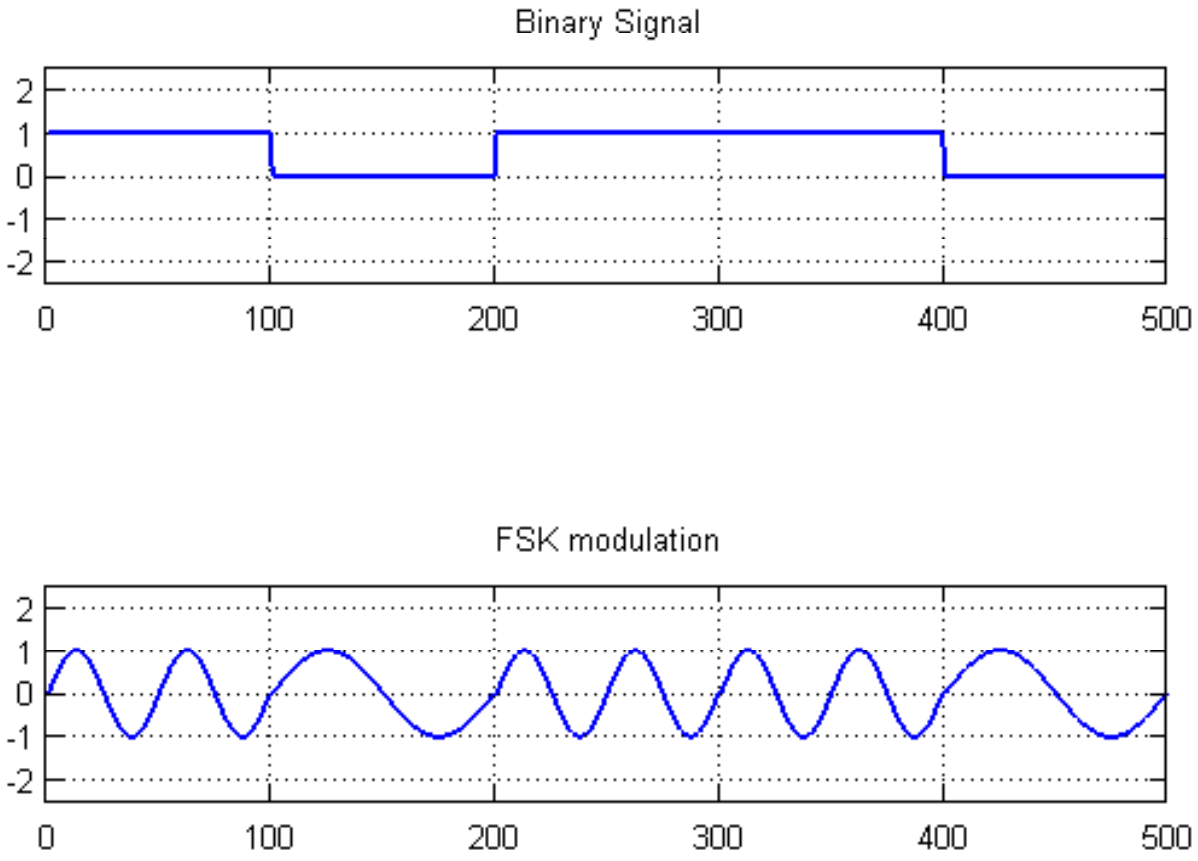


On/Off Keying (OOK)
(special case of ASK)

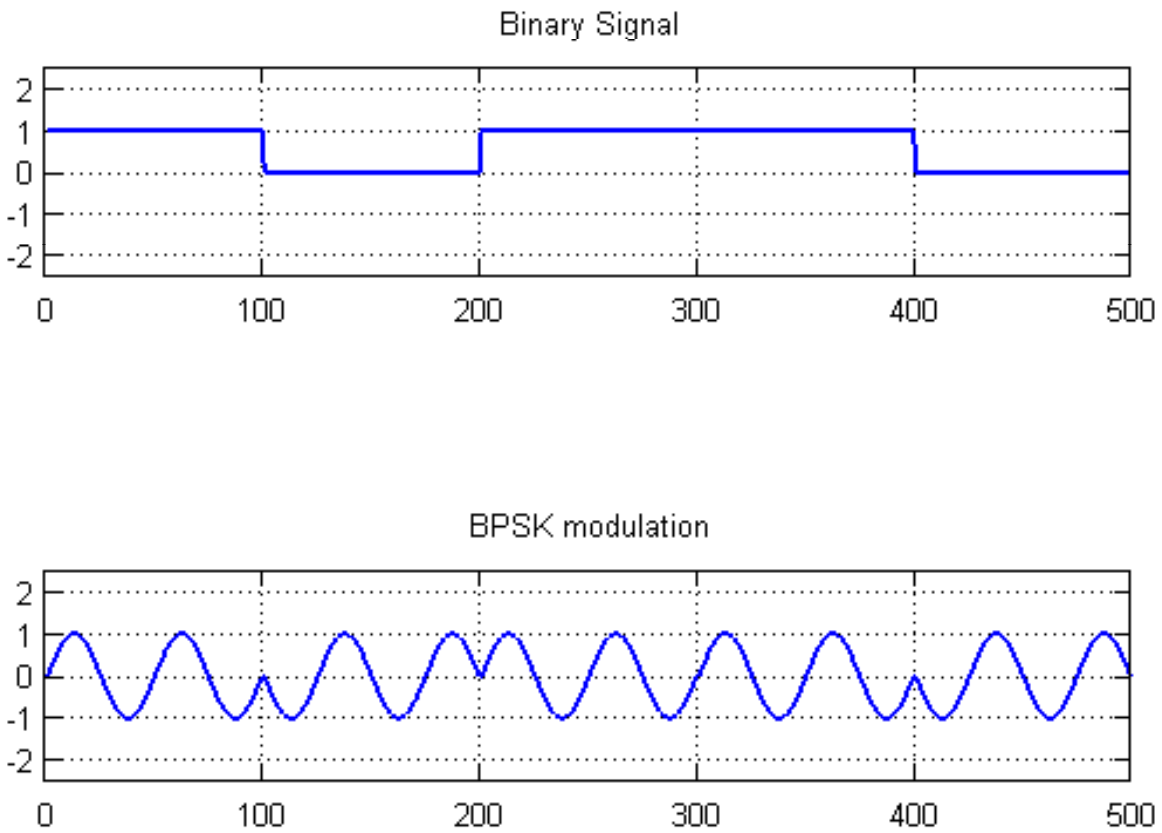




Frequency-Shift Keying (FSK)



Phase-Shift Keying (PSK)



Encoding

- Encoding is the process of converting a message into symbols.
- What changes correspond to data-0 and data-1?

Symbol Rate (Baud)

- The symbol rate is the rate the symbols change per unit of time (baud).
- *Note that only in certain cases is the symbol rate equal to the data rate because each symbol may represent more than one bit.*

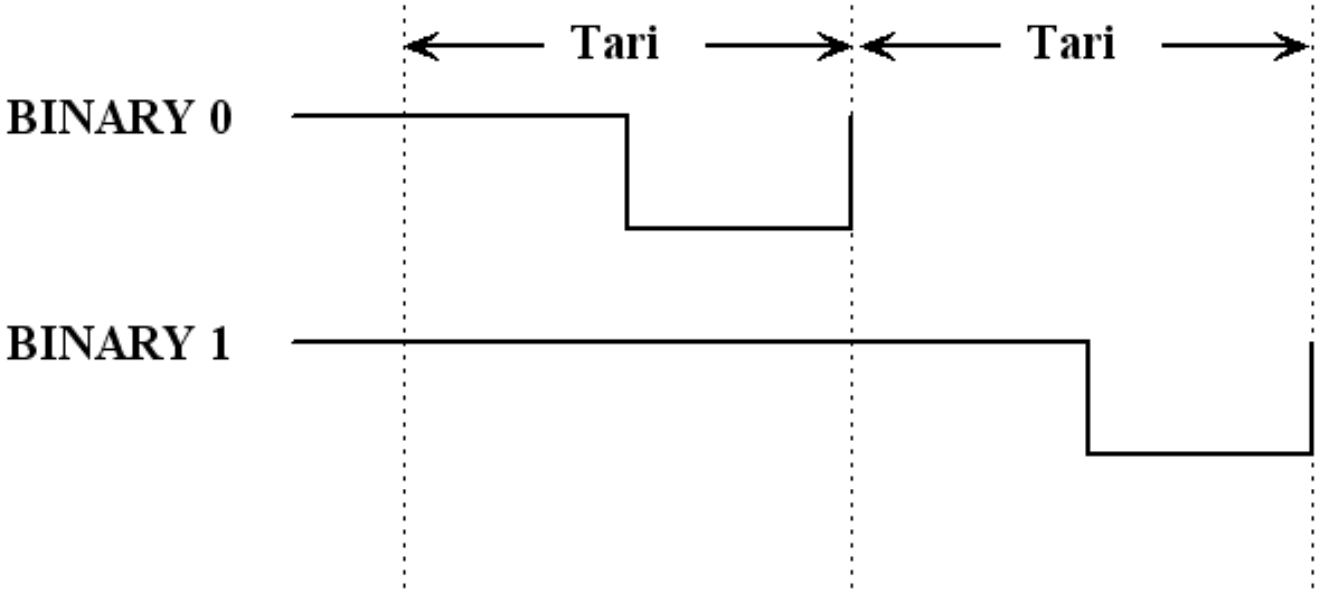
Data Rate (bps)

- The data rate is the rate in bits per second (bps) that information is transferred.
- Assume that a system has four amplitudes. If the symbol rate is 100 symbols per second, what is the data rate in bits per second?

Gen-2 Reader-to-Tag Physical and Link Layers

- Modulation
  - Double sideband amplitude shift keying (DSB-ASK)
  - Single-sideband ASK (SSB-ASK)
  - Phase reversal ASK (PR-ASK)
- Encoding - Pulse interval encoding (PIE)
- Data rate based on Tari
  - Tari 25 microsecond (TYPICAL SETTING)
    - 40 Kilobits per second (Kbps) maximum
    - 27 Kbps average
  - Tari 12.5 microsecond
    - 80 Kbps maximum
    - 53 Kbps average
  - Tari 6.25 microsecond
    - 160 Kbps maximum
    - 107 Kbps average

PIE Encoding



High represents carrier wave
Low represents attenuated carrier wave
Type A Reference Interval (Tari)

Why does a reader use PIE encoding?

- PIE encoding is used so that there is ample radio frequency energy from the reader to power the tag.

Tag Modulation

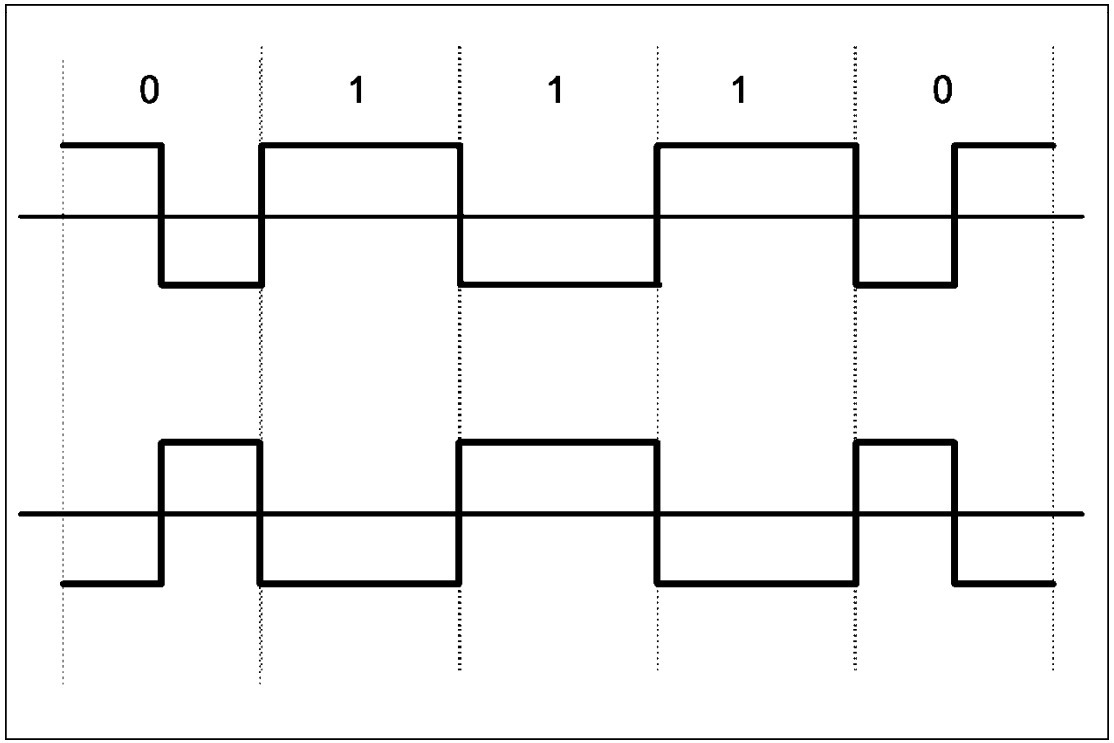
- Tags tend to use variations of FSK
- They frequency shift the baseband frequency, not the carrier frequency
- Example
  - Binary 1: two transitions per symbol
  - Binary 0: three transitions per symbol
- Changing the baseband frequency is also called subcarrier modulation

Gen-2 Tag-to-Reader Physical and Link Layers

- Backscatter modulation
  - Varies reflection coefficient of antenna
  - Switch load on antenna in time with bits, which varies input impedance
  - Varies amount of energy reflected from tag to reader
  - 80 to 90 dB less signal than reader-to-tag (10,000 times weaker!)
- Modulation
  - Amplitude-shift keying (ASK)
  - Phase-shift keying (PSK)
- Encoding – Reader chooses type
  - FM0
  - Miller (M=2, 4, or 8)
- Data rates are variable
  - FM0 [single reader mode] – 40 Kbps up to 640 Kbps
  - Miller (M=2) [multi-reader mode] – 20 Kbps up to 320 Kbps
  - Miller (M=4) [dense reader mode] – 10 Kbps up to 160 Kbps
  - Miller (M=8) – 5 Kbps up to 80 Kbps
  - Typical rates in the lab vary between 60-70 Kbps using Miller (M=4)

FM0 Baseband Data Encoding

- Rules
  - Inverts baseband phase at every symbol boundary
  - Data-0 has a mid-symbol phase inversion



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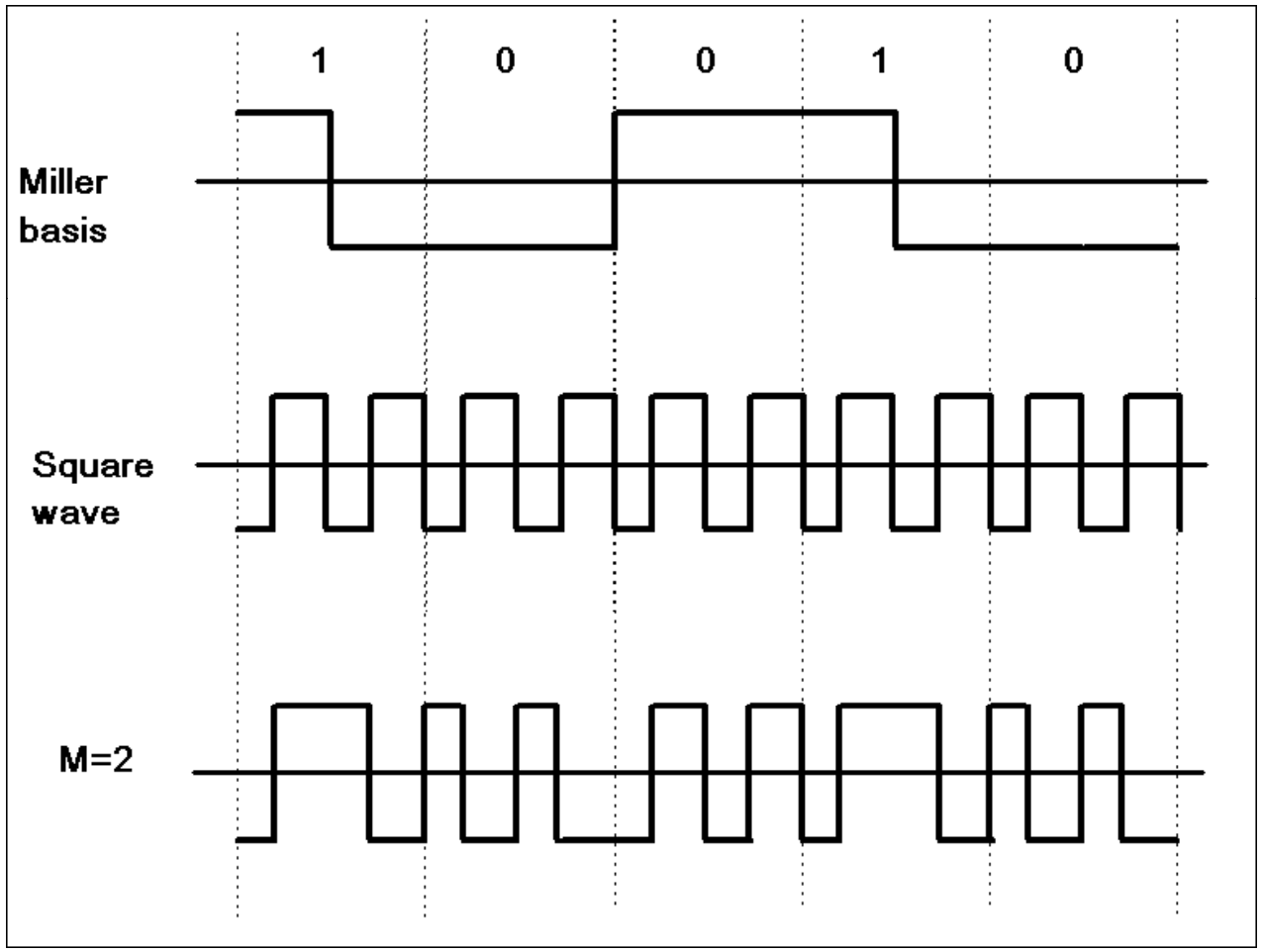
Miller-Modulated Subcarrier

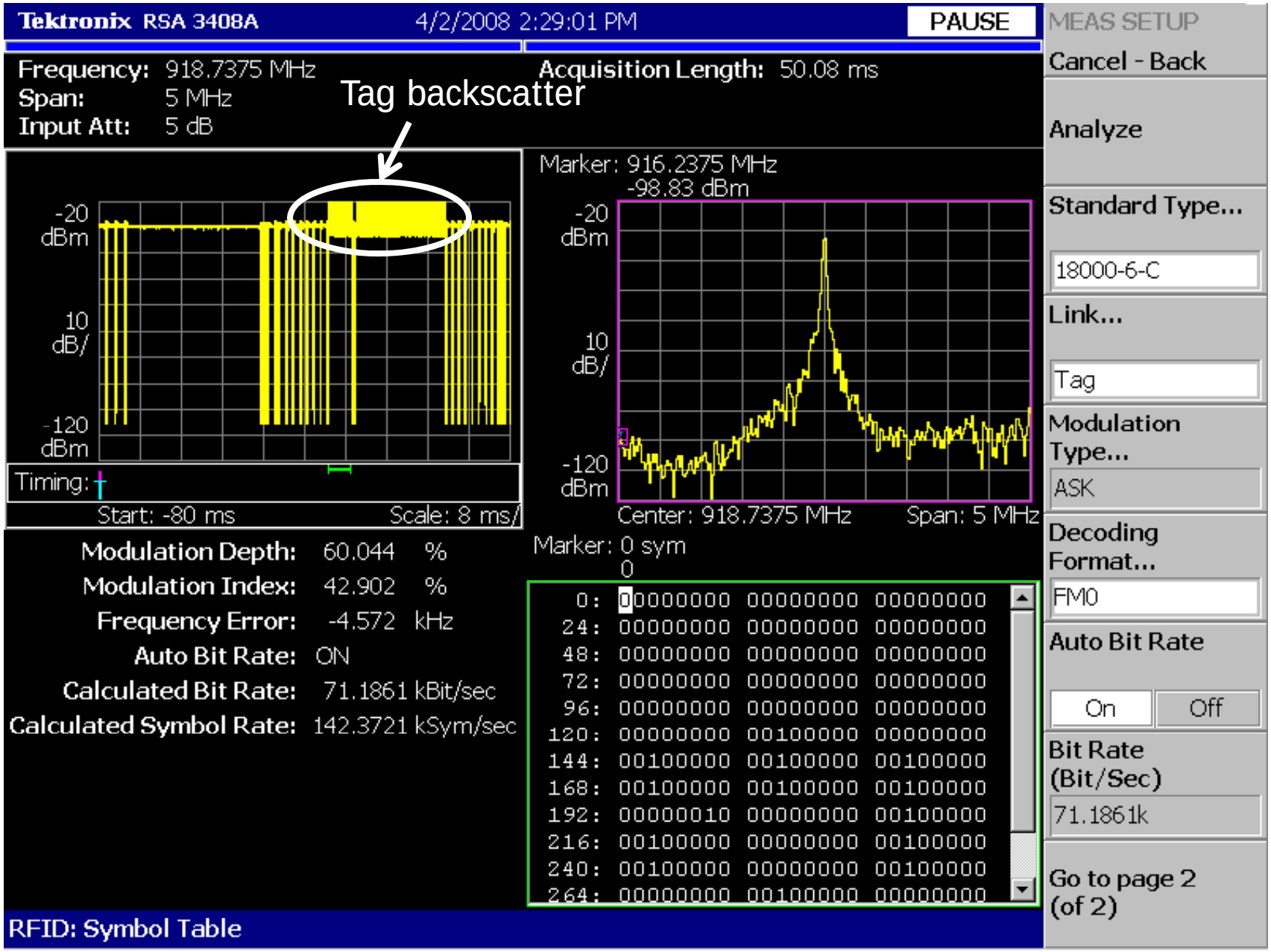
- Rules
  - Inverts its phase between two Data-0s in sequence
  - Phase inversion in the middle of a Data-1 symbol
  - The transmitted waveform is the baseband waveform multiplied by a square wave at M times the symbol rate for M = 2, 4, 8
  - M specified by the reader in Query command
  - Miller encoding has memory. Choice of sequences depends on prior transmissions.

Miller M=2 Example



Miller Modulated Subcarrier cont.

- More transitions per bit make detection easier but reduces the data rate
- Miller modulated subcarrier works better in the presence of noise
- Another advantage of more transitions per second is that the response from the tag is farther from the carrier frequency
- Trade-off of interference rejection vs data rate


Tektronix RSA 3408A
4/2/2008 2:29:01 PM
PAUSE
Frequency: 918.7375 MHz
Span: 5 MHz
Input Att: 5 dB
Acquisition Length: 50.08 ms
Tag backscatter
-20 dBm
10 dB/
-120 dBm
Timing:
Start: -80 ms
Scale: 8 ms/
Marker: 916.2375 MHz
-98.83 dBm
-20 dBm
10 dB/
-120 dBm
Center: 918.7375 MHz
Span: 5 MHz
Marker: 0 sym
0
Modulation Depth: 60.044 %
Modulation Index: 42.902 %
Frequency Error: -4.572 kHz
Auto Bit Rate: ON
Calculated Bit Rate: 71.1861 kBit/sec
Calculated Symbol Rate: 142.3721 kSym/sec
0: 00000000 00000000 00000000
24: 00000000 00000000 00000000
48: 00000000 00000000 00000000
72: 00000000 00000000 00000000
96: 00000000 00000000 00000000
120: 00000000 00100000 00000000
144: 00100000 00100000 00100000
168: 00100000 00100000 00100000
192: 00000010 00000000 00100000
216: 00100000 00000000 00100000
240: 00100000 00000000 00100000
264: 00000000 00100000 00000000
RFID: Symbol Table
MEAS SETUP
Cancel - Back
Analyze
Standard Type...
18000-6-C
Link...
Tag
Modulation Type...
ASK
Decoding Format...
FM0
Auto Bit Rate
On
Off
Bit Rate (Bit/Sec)
71.1861k
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Contact Information

Dale R. Thompson, Ph.D., P.E.
Associate Professor
Computer Science and Computer Engineering Dept.
JBHT – CSCE 504
1 University of Arkansas
Fayetteville, Arkansas 72701-1201

Phone: +1 (479) 575-5090
FAX: +1 (479) 575-5339
E-mail: d.r.thompson@ieee.org
WWW: http://comp.uark.edu/~drt/

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