

In-Building 101

A Primer for RF Distribution Technology

*Presented by
Jack Daniel, Jack Daniel Co.*

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AGENDA

- Overview of Radio Propagation.
- Common Reasons for “Dead Spots”.
- Different Ways to Reduce Dead Spots.
- Types of Signal Boosters
- Distributed Antenna System designs
- FCC Signal Booster Rules
- Signal Booster Codes
- New Signal Booster Developments.
- Questions and Comments.

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Reasons Why In-Building Coverage is Important:

Every Reason You Have an
Outdoor Radio System
applies equally to having
In-Building communications as well.

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*Every time a
First Responder
enters a
High Rise building,
basement, subway or
large mall chances are
Public safety
radio communications
may not be reliable.*

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In-building Industry Nomenclature

- The FCC Rules identify special in-building amplifiers as “Signal Boosters”. Within the wireless industry, a signal booster may also be called a “Bi-Directional Amplifier” or “BDA”. They are the same device.
- Some rf distribution designs may use radiating coaxial cables which are also called ‘leaky coax’.
- A system that includes multiple inside antennas is called Distributed Antenna System or “DAS”.

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In-building Industry Nomenclature

DOWNLINK: The RF direction of flow FROM a base station TO a radio inside the structure.

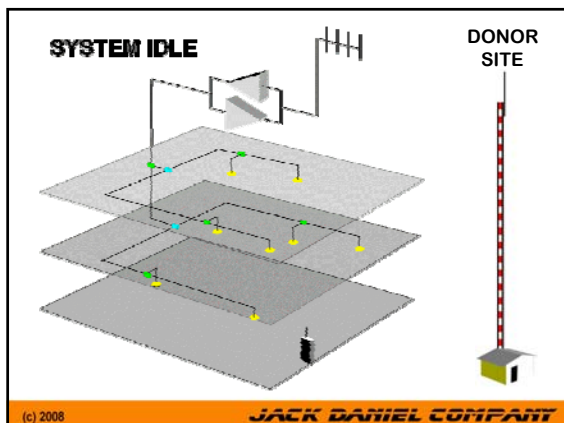
UPLINK: The RF direction of flow TO a base station FROM a radio inside the structure.

DONOR SITE: A distant base or repeater location.

DONOR ANTENNA: The antenna (typically on the roof) that connects the path to the Donor site.

SERVICE ANTENNA: Antennas used inside the structure, or “in-door” antennas.

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In-building Industry Nomenclature

COMPOSITE POWER: The total power of all channels passed in a Class B signal booster.

Note that a Class B signal booster with a 10 watt rated output amplifier will NOT provide 10 watts on all the channels.

For example, 10 equal level channels input to a 10 watt broadband power amplifier will have 1 watt output power per channel.

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In-building Industry Nomenclature

Decibels are mathematical values of RF power levels or ratios. In RF system designs, watts and microvolts are converted to dBm's, a real amount relative to 1 milliwatt power level.

Once all values are converted to dBm, calculations are simply add and subtract.

Gains and losses are stated as RATIOS in dB's (not dBm)

dB's are *logarithmic* so, for example;
 $2x = 3 \text{ dB}$, $5x = 7 \text{ dB}$, $10x = 10 \text{ dB}$ changes

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In-building Industry Nomenclature

Distributed Antenna System "DAS"

The most commonly used term used to identify an in-building system consisting of multiple antennas placed inside the structure.

Cellular system engineers often interpret DAS as only a term that only applies to cellular systems.

"DAS" is used as verbal shorthand for almost all in-building RF distribution systems.

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In-building Distribution Types

The cellular industry has established term that are now being adopted by other in-building system designers :

PASSIVE: The portions that have no active devices, such as coax directly connected to a station or BDA with no further amplifiers.

ACTIVE: A DAS system that includes rf amplification or RF conversion, such as in-line boosters or RF over fiber).

HYBRID: A system that has both Passive and Active portions. This is the most common after Passive.

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Radio Signal

Propagation

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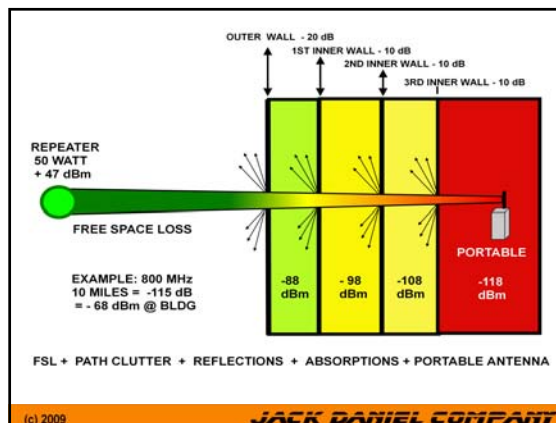
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Radio Signal Propagation

- Radio signals travel from point to point in a fashion similar to light.
- Radio signals can 'penetrate' some distance through many types of non-metallic obstacles like glass, wood, bricks, trees, fog, etc.
- As radio signals pass through ANY obstacle, even air, they lose strength.

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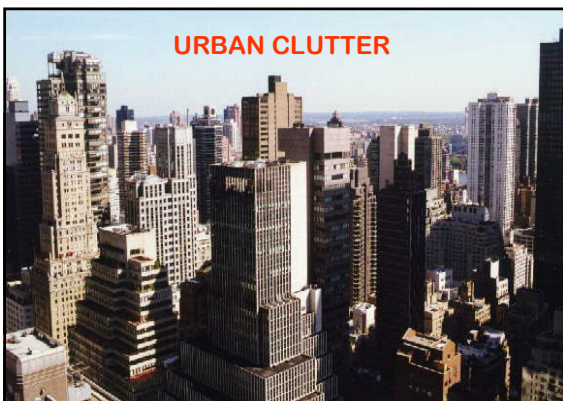
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URBAN CLUTTER



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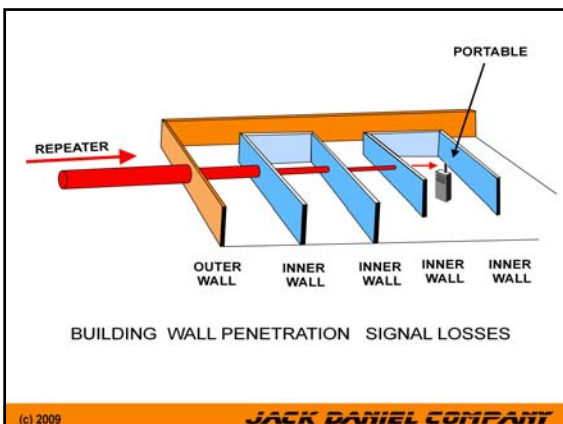
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Radio Signal Propagation

- When radio signals encounter metallic and masonry obstacles the signal is attenuated greatly and portions may be reflected away from the desired path.
- Weakened radio signals reduce the range of the radio system, both transmit and receive.
- Portables may receive in a structure but not send because of their lower transmit power.

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Typical Areas of Poor RF Coverage

- Buildings, especially basement levels.
- Subways, mines.
- Parking Garages.
- Naturally Shadowed Areas :
(Canyons, behind hills, river bottoms, etc.)

In Public Safety
A dead Spot can be
a DEAD Spot!

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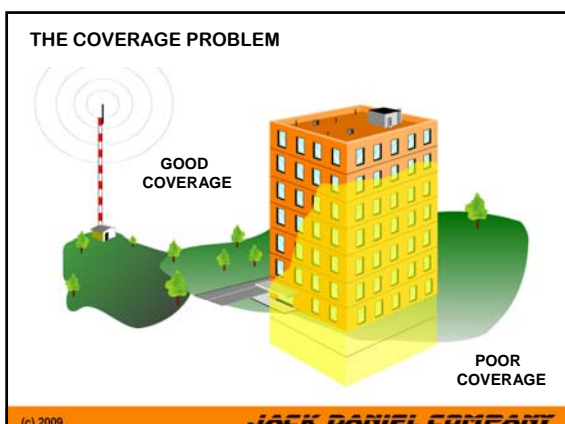
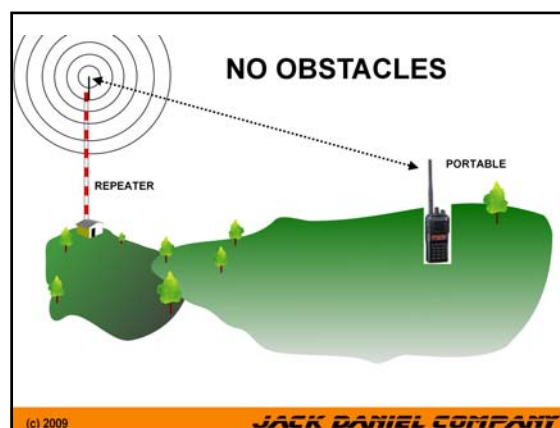
Extending Radio System Range

SIGNAL BOOSTERS ARE
NOT
INTENDED TO BE USED TO **INCREASE**
THE OUTDOOR RANGE OF A
RADIO SYSTEM,
BOTH BY DESIGN AND FCC RULES!

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In-Building Coverage Solutions

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Blocked Signal Solution #1 Increase Transmit Power

- Portable Transmit power wont be increased, so only "Talk-Out" is improved.
- Will require FCC license modification.
- May have FCC ERP limitations.
- Will have to increase power by many multiples to have any notable improvement.
- Provides NO improvement if signal is blocked by a major obstacle. (Mtns, Basements, etc.)

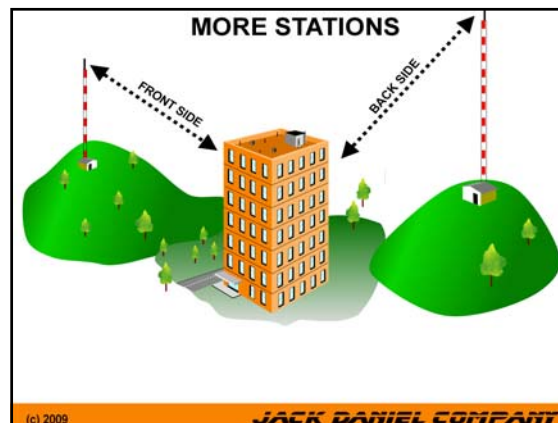
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Blocked Signal Solution #2 Build More Base Stations

- VERY expensive solution, especially when problem is in many widely scattered areas.
- Multiple bases or repeaters require additional equipment to 'network' them to work as an integrated, manageable system.
- Control circuits (microwave, telco lines) are required to link the sites together.
- Additional control console positions may be required.

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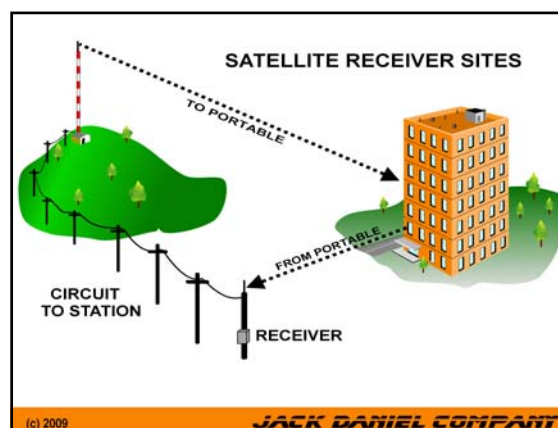
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Blocked Signal Solution #3 Use Satellite Receivers

- Satellite receiver systems only address the "talk-back" side of the radio conversation.
- Additional equipment (voting panels, console positions, etc.) will be required also.
- Links (microwave, telco lines, etc.) are required to all satellite receiver sites, causing higher monthly operating costs in most cases.

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Blocked Signal Solution #4 Add Small "Fill-In" Repeaters inside problem areas.

- May requires additional radio channels for "cross-band" communications.
- Only one channel may be available.
- Will require additional FCC licenses & fees.
- Users have to know when to switch channels when moving from inside to outside and vice versa. A highly error prone procedure.
- A 'jammed' fill-in repeater can block the whole radio system.

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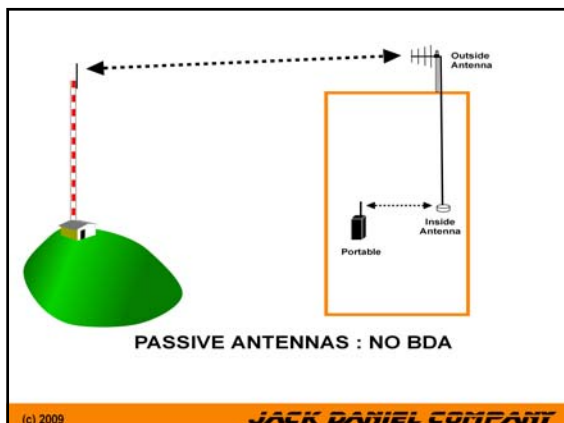
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Blocked Signal Solution #5 Install "Passive" Antennas

- Low cost, low maintenance choice but only works well in less than 10% of cases.
- Requires VERY strong signals outside of the blocked area.
- Generally, must be less than 2 miles from base station/repeater site.
- User doesn't have to switch channels.
- If planned properly, signal boosters can be added if needed without wasted investment.

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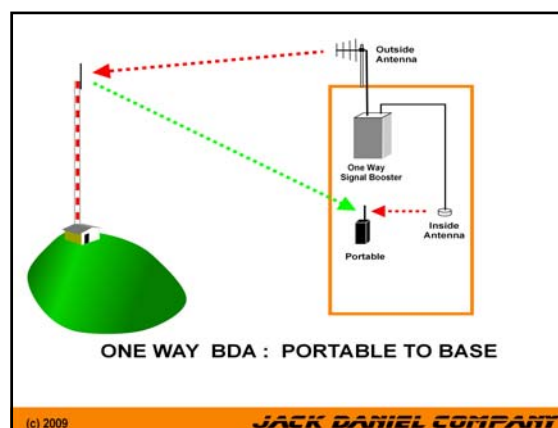
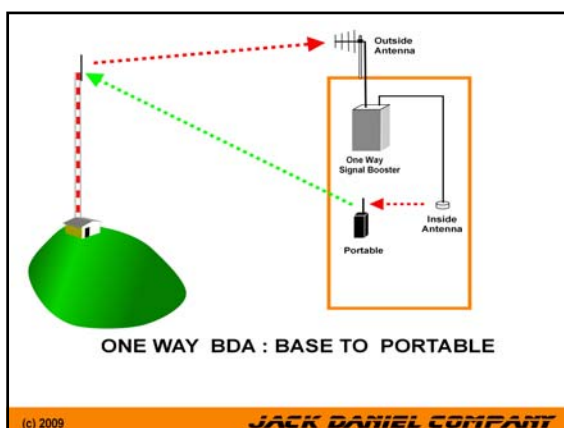
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Blocked Signal Solution #6 Install "One-way" Signal Boosters

- Can solve many unbalanced system problems where either the "talk-out" or "talk-in" is OK but the other is unsatisfactory.
- Outside and Inside antenna system is similar to passive antenna system.
- User doesn't have to switch radio channels.
- Also applies to in-building 1 way paging.
- Most economical signal booster system.

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Blocked Signal Solution #7 Use Portable Repeaters

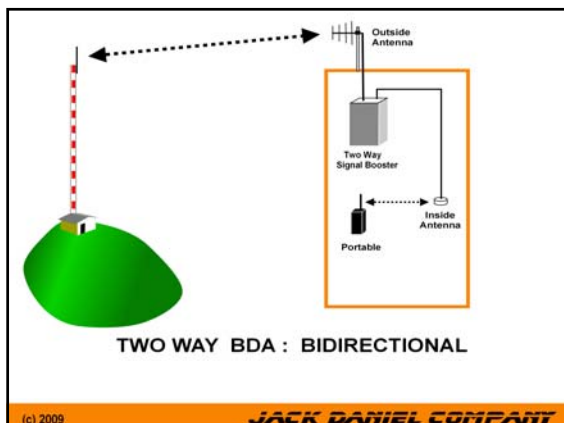
- Used by some Fire Departments
- Can improve coverage up to about 5 floors.
- Requires logistical coordination to have at the right place at the right time.
- Does not work for Simplex fire channels.
- Users may have to switch channels.
- Users may have to 'learn' this may not cover higher floors in a high rise building.

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Blocked Signal Solution #8 Install "TWO-way" Signal Boosters

- Solves most obstructed site problems, for "talk-out" and "talk-in" paths both.
- Outside and Inside antenna system is similar to passive antenna system.
- Users doesn't have to switch channels.
- The most common signal booster application.
- Multiple Frequency bands can be handled.
- Costs vary, dependent upon frequencies employed and complexity.

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TYPES OF SIGNAL BOOSTERS

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Types of Signal Boosters

- Channelized (FCC Class A)
- Broadband (FCC Class B)
- One-Way or Two-Way
- Single Band (i.e. VHF, UHF, 800, 900)
- Multi-Band (i.e. UHF AND 800)
- Customs: Made to specific requirement.

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CUSTOM configured signal boosters may:

- Serve more than one frequency band, such as UHF + 800, or 450 + 480 MHz, etc. (System designs may also use more than one signal booster to obtain multiple bands)
- Used mixed signal booster types, such as Class B for the Downlink path and Class A for the Uplink path. These are sometimes called hybrid signal boosters"

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Less common types of signal boosters are;
_ IN-LINE signal boosters, which extend distribution coax cable lengths by boosting the signals at the end of a long coax cable.

Typically this is considered when the distribution losses at the highest frequency reach 25 to 30 dB loss.

- ONE WAY signal boosters maybe used for paging or when only one direction needs improvement.

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All Emergency Equipment is NOT Equal



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All Signal Boosters are NOT Equal

Cheap Signal Boosters
designed for Consumer
Applications Can and Will
Let you Down at the time
You Need Them Most !



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Common Mission Critical (NFPA) Signal Booster Features:

- Non-vented housings; NEMA 4, 4X
- 12 hour Battery Back-up Compatibility
- Fail-safe redundancy and design.
- Remote Failure Alarming.
- Historical Performance Data.
- Non-Disruptive Testing while in Service.
- Factory Certified Technicians.
- Retuning and Band expansion compatibility.
- Radio technology compatibility; i.e. Delay

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FCC Class A Versus FCC Class B Signal Boosters

Basic Definitions:

Class A (channel selective) pass single channels.
Sometimes called 'channelized' or channel
selective.

Class B (band selective) pass a 'window' of
multiple channels. Sometimes called 'broadband'
or band selective.

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FCC Class A Versus FCC Class B Signal Boosters

Broadband	Channelized
<ul style="list-style-type: none"> • Amplifies everything within a Passband. • Low cost for many channels. • Moderate Output Power levels. • FCC Class B 	<ul style="list-style-type: none"> • Only amplifies specific channel(s) • Moderate cost for few channels. • Optional High Output Power • FCC Class A

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Class A : Primary Benefits

- Single Channel selectivity can reduce unwanted signal amplification.
- Modern single channel signal boosters are software programmable, but not always in the field.
- Gain and AGC can be channel specific
- Some models are available in high power versions, up to about 25 watts per channel.

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Class A : Disadvantages

- Expensive when compared to Class B.
- Number of channels per signal booster can be limited, especially when used in large urban systems.
- Propagation delays may result in poor performance in signal overlap areas, especially outdoor fill-in applications. Some models can be reprogrammed to wider bandwidths and operate as Class B to reduce delay
- Higher back-up power requirements.
- High power models may require site specific FCC licensing, RF exposure checks, higher antenna isolation.

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Class B : Primary Benefits

- Most economical for multichannel systems, many equipment sources.
- Most commonly used type of all signal boosters
- Very low delay makes 'modulation transparent'.
- Quality brands compatible with refarming. Cheap units cannot be retuned.
- Available in all bands including VHF and UHF.
- Three grades: Public Safety, Enterprise, Consumer

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JACK DANIEL COMPANY**Class B : Disadvantages**

- Bandwidth can allow undesired channels to be amplified. This is a operational characteristic that can be addressed in system designs.
- Very strong undesired channels may effect performance and output power of desired channels.

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JACK DANIEL COMPANY**Session Break****Please stay in the room.****Class continues in 10 minutes****With additional handouts*****Signal Booster Specifications Next***

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JACK DANIEL COMPANY**OVERVIEW OF IMPORTANT
SIGNAL BOOSTER
SPECIFICATIONS****Maximum Input power level****1 dB Compression point****3rd Order Intercept****Noise Figure****Propagation Delay**

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JACK DANIEL COMPANY**MAXIMUM INPUT POWER LEVEL**

This specification may seem obvious but cheap consumer signal boosters often have very low input power limits.

In quality signal boosters this signifies input power level where damage may occur. (This especially applies to RF over Fiber devices.)

The higher the input power rating the better

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JACK DANIEL COMPANY**1 dB COMPRESSION POINT**

The 1 dB compression point is the Output Level where an increase of the input level resulted in 1 dB less than the expected output level.

I.e.: A 2 dB input increase only causes 1 dB output increase. This indicates the amplifier is no longer operating in it's linear range.

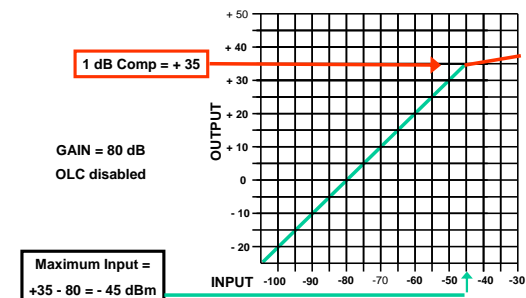
The 1 dB compression level should be considered the absolute maximum operating input level to the signal booster to maintain lowest IM output, under all input conditions.

The higher the 1 dB compression point the better.

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1 dB COMPRESSION POINT EXAMPLE



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3rd ORDER INTERCEPT POINT

The 3rd Order Output Intercept Point (3OIP) is a *theoretical* level where the 3rd Order IM product output levels equals the output level of two fundamental input carriers.

The 3 OIP specification is needed to prevent IM.

3 OIP IM's are the 2A-1B, 2A+1B IM products.

Note: 2nd Order (A+B, A-B) are negligible because they fall outside the passband of the filters and are attenuated greatly.

The higher the 3rd order Intercept point the better

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3rd ORDER INTERCEPT POINT

ALL amplifiers generate IM,
the challenge is to manage the IM levels.

$$\text{IM(dBm)} = 3 * \text{Pout (dBm)} - 2 * 3\text{rd OIP(dBm)}$$

3 to 1 Rule: Third Order IM will go down 3 dB for every 1 dB of carrier reduction.

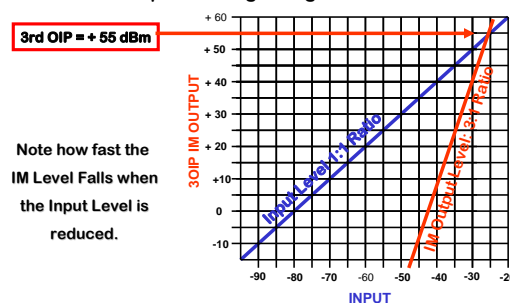
Therefore, a 1 dB reduction of the 3rd OIP specification will increase IM 2 dB.

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3rd ORDER INTERCEPT POINT

Example: 80 dB gain signal booster



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NOISE FIGURE

The 'noise figure' is a measurement of the RF noise added to the output signals by the amplifiers within the signal booster.

Caution: Some manufacturers specify the ideal amplifier only specifications. Others provide the 'true' input to output noise figure, which has to be the higher.

The lower the Noise Figure the Better.

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PROPAGATION DELAY

Propagation delay is the time added to the signal travel time within the signal booster.

High propagation delays can be destructive in areas where the direct signal meets the signal booster output signal. This is a primary concern when using Class A signal boosters.

Propagation delays of 15 microseconds are currently considered acceptable in any system.

The less the propagation delay the better.

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CLASS B SIGNAL BOOSTER SENSITIVITY

Class B signal boosters do not have a input threshold or 'sensitivity like a repeater has.

NF sets the minimum Input Level.

-174 dBm is the accepted reference for the minimum natural noise level for 1 Hz bandwidth

Minimum Noise Level (dB) at Input =

$$-174 + 10 \log(BW) + NF(dB)$$

(BW = bandwidth in Hertz)

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JACK DANIEL COMPANY**CLASS B SIGNAL BOOSTER SENSITIVITY**

The Noise limited minimum Input Level is the "minimum sensitivity" of a signal booster, without considering noise from the antenna.

You must add the desired S/N ratio to determine the **minimum possible input signal level.**

NOTE: The ambient noise is often greater than the minimum acceptable input signal level.

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JACK DANIEL COMPANY**CLASS B SIGNAL BOOSTER SENSITIVITY**

Example: Minimum Input for a single channel.

Signal Booster NF = 3.5 dB

Signal Booster Gain = 80 dB

1 Channel Bandwidth = 25 KHz.

Minimum Acceptable S/N = 20 dB (= 3.4 DAQ)

$$-174 + 10 \log(25,000) + 3.5 =$$

$$-174 + 44 + 3.5 = -130.5 \text{ dBm 'noise threshold'}$$

$$-130.5 + 20 = -110.5 \text{ dBm Minimum Input Level}$$

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JACK DANIEL COMPANY**CLASS B SIGNAL BOOSTER SENSITIVITY**

Output resulting from minimum Input level for a single channel :

From the preceding example:

$$-110.5 \text{ dBm Min. Acceptable Input Level}$$

Signal Booster Output level = Input + Gain.

$$-110.5 + 80 = -30.5 \text{ dBm Output level.}$$

This is a usable signal level for nearby portables, but marginal for a typical coax distribution system.

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JACK DANIEL COMPANY**CLASS B SIGNAL BOOSTER SENSITIVITY**

The better way to calculate the ideal input signal level is to estimate based on maximum output level:

A signal booster with 80 dB gain and +30 dBm output level at the 1 dB compression point ;

$$+30 - 80 = -50 \text{ dbm desired input level.}$$

This input level may not always be achievable.

Industry practice has established approximately -75 dBm as the lowest desired signal level.

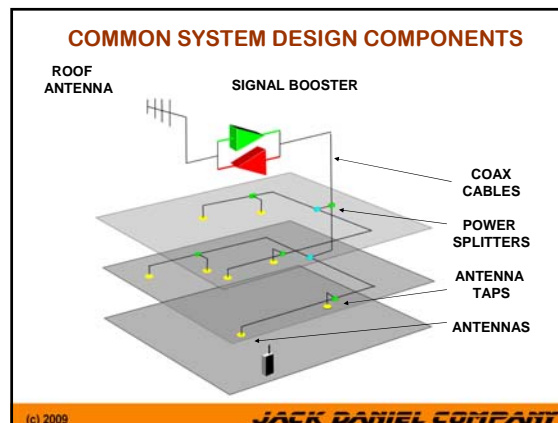
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THE CLASS B SIGNAL BOOSTER SOLUTION

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SYSTEM DESIGN: BEST PRACTICES:

Minimum Signal Level to Portable : - 95 dBm or greater

Minimum Coverage: 90% overall, 95% in critical areas.

Public Safety "Must Cover" areas:

Fire Prevention and suppression Facilities.
Underground areas Such as parking and basements.

Emergency exit routes, especially stairwells in high rise structures.

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SYSTEM DESIGN: BEST PRACTICES:

**ALWAYS USE THE MINIMUM GAIN
AND LOWEST POWER LEVELS
NECESSARY TO
MAINTAIN RELIABLE COVERAGE.**

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INTERFERENCE IN SIGNAL BOOSTER SYSTEMS

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INTERFERENCE MANAGEMENT PRACTICES

- Use filters optimized for your system bandwidth.
- Use filters with at least 35 dB rejection of adjacent bands. i.e. +/- 1 MHz.
- Use directional antennas to reduce signal levels from other directions and increase desired levels.
- Use the structure to add blockage from unwanted directions.

Tip: Undesired channels that are -20 dB or more lower than yours has minimal impact on Class B signal booster performance.

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Filter Best Practices

Specify the Filter bandpass as narrow as practical.

A 15 or 18 MHz passband used for a 5 MHz requirement is an invitation for future problems.

Use high performance filters with high selectivity.

A low selectivity 5 MHz filter offers minimal improvement over 10, 15 or 18 MHz filters.

High Performance bandpass filters are large.
It's physics.

High Performance bandpass filters cost more.
The long term benefits outweigh initial cost.

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Filter Best Practices

Cheap, consumer grade signal booster filters are seldom re-tunable.

Signal boosters with 15 or 18 MHz passbands defeat the effect of 800 rebanding.

FCC Rules **may** be revised to limit signal booster bandpasses to the service they can support. (i.e. Sprint Nextel and other 800 services cannot share the same signal booster.)

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DONOR ANTENNA SELECTION

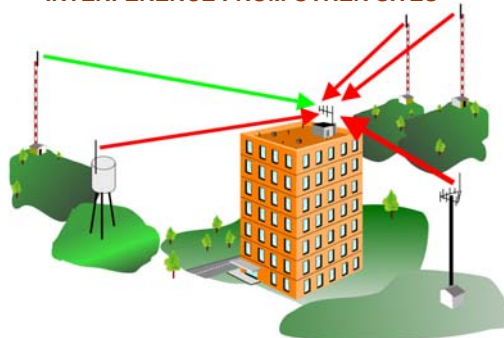
Always use directional antennas even when the donor site is near.

The following slides show the advantages

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INTERFERENCE FROM OTHER SITES



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OVER THE AIR INTERFERENCE IMPACT TO YOU:

If system is designed properly, external interference is not a problem in all but a few extreme situations.

Directional Roof antenna and placement can dramatically reduce interference.

Public Safety grade Signal Boosters use high performance filter designs with pass bandwidths that match your radio system.

Signal boosters that amplify public safety and cellular at the same time are problematic.

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The impact of undesirable signals on Class B (band selective) is often exaggerated.

Assuming multiple signal levels of the same level, here is the relative impact on your output levels if you have a 10 channel trunked system:

Your 10 channels. Output per channel: +23 dBm
Add 10 unwanted channels: +20 dBm per channel
Add 30 unwanted channels: +17 dBm per channel

These are example levels but the impact is the same relationship for any Class B signal booster. The desired signals are reduced 3 dB for each doubling of total channels.

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Impact of number of equal power carriers on a typical Class B signal booster

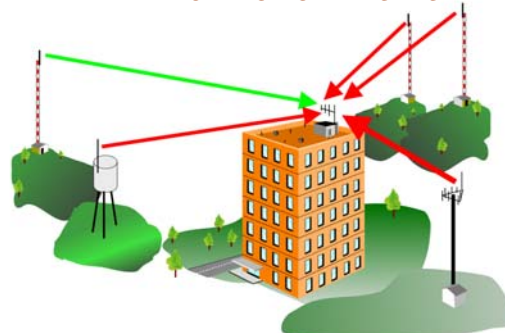
- 1 Carriers: +30.0 dBm per channel
- 2 Carriers: +27.0 dBm per channel
- 4 Carriers: +24.0 dBm per channel
- 8 Carriers: +20.0 dBm per channel
- 16 Carriers: +18.5 dBm per channel
- 32 Carriers: +14.0 dBm per channel
- 40 Carriers: +13.0 dBm per channel
- 50 Carriers: +10.0 dBm per channel

Tip: Always design for future increases in undesired carriers within the filter passband.

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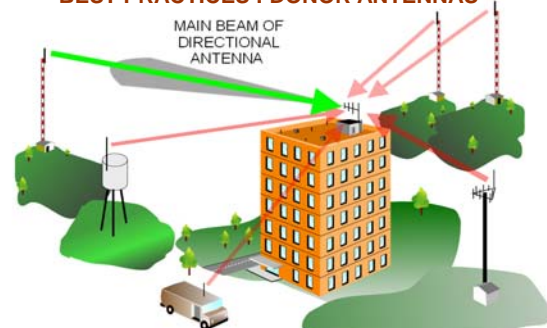
INTERFERENCE FROM OTHER SITES



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BEST PRACTICES : DONOR ANTENNAS



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INTERFERENCE TO OTHERS



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INTERFERENCE IMPACT ON OTHERS:

If system is designed properly, external interference is a non-problem in all but a few extreme situations.

Nearby receiver desense biggest potential problem.
> 500 ft separation eliminates almost all problems.

Multi-BDA composite power can only impact nearby sites normally, using minimum gain and low NF.

FCC RULE: ALL In-building is 'secondary' and cannot cause OBJECTIONABLE interference.

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CALCULATING BDA NOISE LEVEL IMPACT

REMEMBER, IT IS THE NOISE WITHIN THE RECIEVERS CHANNEL BANDWIDTH THE RECEIVER SEES, NOT THE WHOLE BDA BANDWIDTH.

EXAMPLE: BDA WITH 6 DB NF, 60 DB GAIN AND NO INPUT SIGNAL WILL OUTPUT A TOTAL BANDWIDTH NOISE POWER OF ~ - 43 DBM

THAT CONVERTS TO ~ - 64 DBM IN A 25 KHZ PASSBAND

A FREE SPACE SEPARATION OF 60 FEET WILL PROVIDE -110 DB ISOLATION TO A NEARBY RECEIVER.

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MULTI-BDA COMPOSITE NOISE TO DONOR

AS THE USE OF BDAS INCREASES SO DOES THE NUMBER OF BDAS DIRECTED TO THE SAME DONOR SITE.

THE COMPOSITE (TOTAL) NOISE LEVELS CAN BE HIGH ENOUGH TO DESENSE A NEARBY DONOR SITE

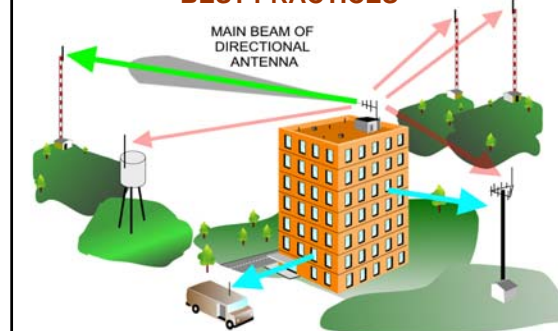
COMPLEX CALCULATIONS ARE REQUIRED TO PREDICT THE IMPACT OF COMPOSITE NOISE LEVELS.

SOLUTIONS: LOWER LEVELS AND FEWER BDAS

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BEST PRACTICES



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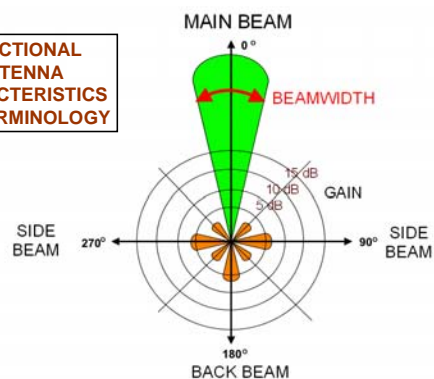
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USING THE NULLS IN DIRECTIONAL ANTENNA PATTERNS TO REDUCE INTERFERENCE

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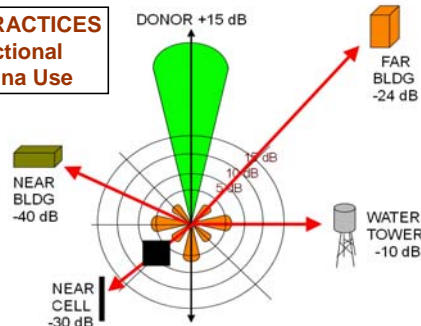
DIRECTIONAL ANTENNA CHARACTERISTICS AND TERMINOLOGY



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BEST PRACTICES Directional Antenna Use



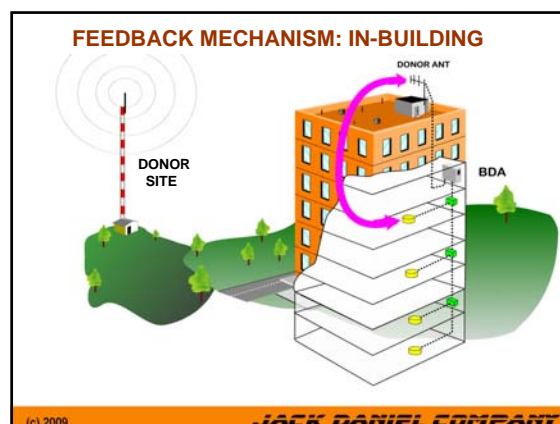
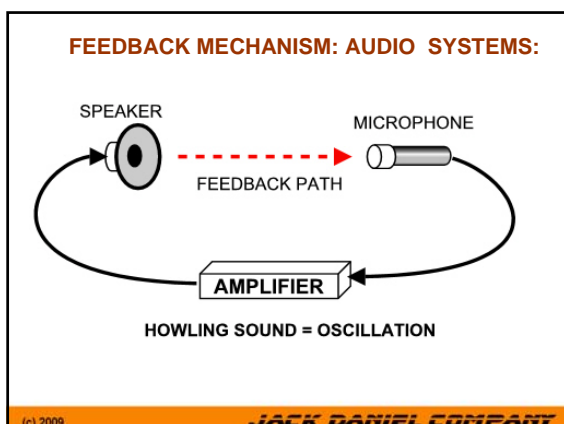
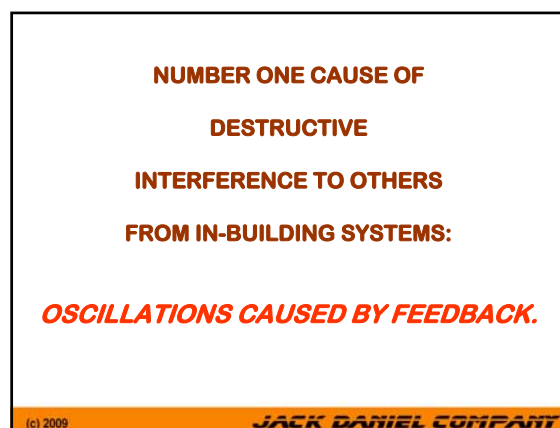
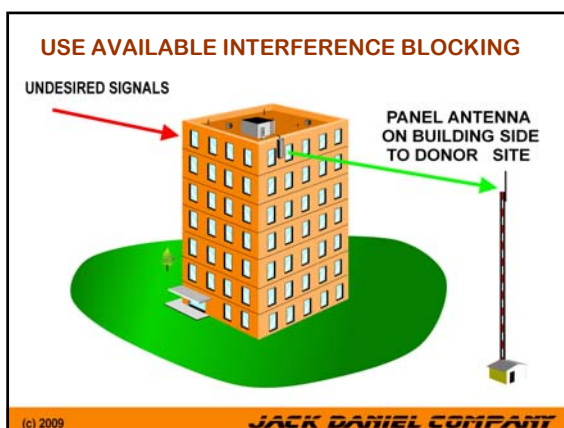
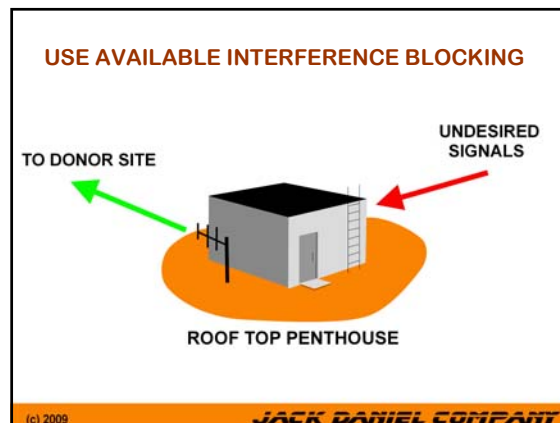
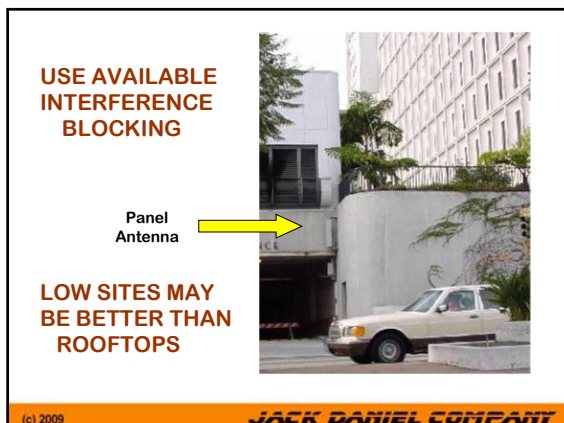
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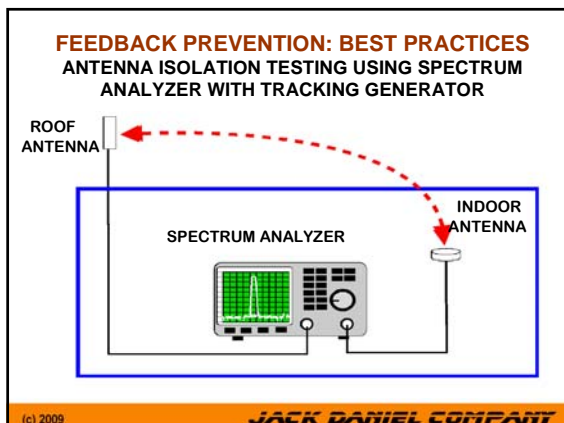
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USING AVAILABLE PATH BLOCKING TO REDUCE INTERFERENCE

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FEEDBACK PREVENTION : BEST PRACTICES

The **MINIMUM** Roof Antenna to any inside antenna isolation must be at least 15 dB greater than the highest operating gain setting of the signal booster:

Example: Signal Booster gain = + 70 dB
 + 15 dB

Minimum Antenna Isolation read on spectrum analyzer should be > 85 Db

Newer Digital system designers are specifying 16 to 20 dB isolation.

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BEST FEEDBACK PREVENTION REVIEW

- Use minimum reliable gain settings and power levels.
- Use Directional antenna on roof (Donor antenna).
- Don't place inside antennas near windows or doors.
- Do not use excessive bandwidth, such as public safety + cellular in one signal booster.
- Select signal boosters with overall low Noise Figures.

ALWAYS HAVE GAIN + 15 dB MINIMUM ANTENNA TO ANTENNA FEEDBACK PROTECTION.

NEVER RELY ON AGC CIRCUIT OPERATION AS A SUBSITUTE FOR GOOD SYSTEM DESIGN PRACTICE.

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Always Be a Good RF Neighbor

The output noise level of signal boosters can impact other nearby receivers operating within the uplink passband.

Some of these receivers may be your own.

If you receive a complaint, be sure everyone is using appropriate measurement techniques.

A spectrum analyzer based noise power measurement is only valid if the measurement bandwidth is **equal to the receivers bandwidth** and on the receivers frequency.

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Session Break

Please stay in the room.

Class continues in 10 minutes

With additional handouts

Signal Booster System Design Next

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DESIGN AND IMPLEMENTATION OF IN-BUILDING WIRELESS DISTRIBUTION SYSTEMS

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THE NEED FOR WIRELESS SIGNAL ENHANCEMENT IN OBSTRUCTED LOCATIONS HAS BECOME ROUTINE WITH OTA BDA SOLUTIONS USUALLY

THE "BDA" TECHNOLOGY AND PRACTICE HAS BECOME MORE PROFESSIONAL AND EXACTING

PROFESSIONAL INTEGRATOR TRAINING HAS GROWN, WITH FORMAL CERTIFICATION SCHOOLS OVER THE LAST 3 YEARS, SUCH AS THE GES PROGRAM

http://www.bird-technologies.com/training/in-building_coverage.pdf

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THE **OBJECTIVE** IS BETTER
WIRELESS COVERAGE

THE **CHALLENGE** IS TO USE THE
MINIMUM
RELIABLE SIGNAL LEVELS
EVERYWHERE YOU NEED IT

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JACK DANIEL COMPANY

BASIC SYSTEM DESIGN CONSIDERATIONS

1. SUFFICIENT SIGNAL LEVELS
 - FROM DONOR TO BDA - DOWNLINK
 - FROM INDOOR ANTENNA TO PORTABLES
 - FROM PORTABLES TO BDA - UPLINK
 - FROM BDA TO DONOR SITE
2. EFFICIENT IN-BUILDING DISTRIBUTION
 - DISTRIBUTED ANTENNA (DAS)
3. MINIMUM RF POWER REQUIREMENTS

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ADVANCED SYSTEM DESIGN CONSIDERATIONS

- BROADBAND DISTRIBUTION SYSTEM CAPABILITY FOR MULTI-BAND AND FUTURE CHANGES
- INTERFERENCE TO YOU
 - UNDESIRE INBAND CARRIERS
 - INPUT OVERLOAD (3IOP POINT, AGC RANGE)
- INTERFERENCE FROM YOU
 - FEEDBACK - OSCILLATIONS
 - OUT OF BAND NOISE
 - BDA GENERATED I.M.

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THE OLD "BDA" INDUSTRY HAS CHANGED.

MODERN IN-BUILDING SYSTEMS
ARE CALLED
DISTRIBUTED ANTENNA SYSTEMS
OR "DAS" INSTALLATIONS

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CHANGES IN SYSTEM DESIGNS

- Distributed Antenna Systems (DAS) now dominate over Radiating cable.
- Indoor antenna patterns are better controlled.
- Broadband and multiband passive distribution components (antennas, splitters, decouplers, etc)
- Signal boosters are more serviceable and rugged.
- "Smart" BDAs are becoming common.
- RF over Fiber use is expanding rapidly.

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CHANGES IN SYSTEM DESIGNS

Mission Critical applications are now demanding RF distribution system designs including:

- Compatibility to Current and future digital Modulation types (Including TDMA)
- 800 Retuning capability
- Minimized Multipath delay, especially for data
- Remote Control , Test and Alarms via PSTN, modems and Internet type protocols.

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COAXIAL CABLE

DAS

TECHNIQUES

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In DAS, standard non-radiating cable is used and antennas are placed at intervals using decouplers.

DAS antennas have less loss than radiating coax due to high 'coupling loss' of radiating cables.

Radiating cable can be cheaper than DAS but more cable may be required to get coverage equal to DAS.

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RADIATED POWER COMPARISON DAS VERSUS RADIATING COAX

> Radiating Cable: - 65 dB coupling loss at 20 feet.

> DAS using -10 dB decoupler :

- 10 dB plus 20 ft. free space loss = 10 + 46 = 56 dB

The DAS -10 dB decoupler reduces through loss by -1 dB each and Radiating cable through loss is at least -1 dB /100 ft more than non-radiating cable, DAS will have 10 dB advantage when DAS antennas are placed at 100 ft intervals. (Based on 800 MHz)

The DAS advantage is even greater at VHF and UHF.

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RADIATING COAX CONSIDERATIONS

Radiating cable installations can be less expensive than DAS due to the cost of decouplers, antennas and connectors used in DAS.

Radiating cable is often the best choice when coverage is 'linear' as in a tunnel.

When there are sufficient RF levels, Radiating cable can cover large distances perpendicular to the cable. it is not limited to 20 feet. For example,

20' coupling loss = -65 dB

40' adds 6 dB = -71 dB

80' adds 12 dB = -77 dB

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IN-BUILDING ANTENNAS

Antenna types and location can greatly influence how a DAS works.

Past techniques are often compromises that are no longer necessary.

The driving coverage concept is;
Put just enough signal level to have reliable coverage every place you need it.

Brute force designs are wasteful and often give inadequate coverage and create interference.

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IN-BUILDING ANTENNAS

One common mistake is the location of antennas.

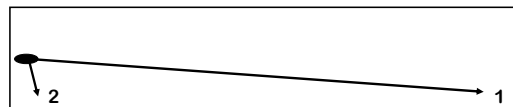
Placing the antenna at user height can cause the uplink signals to exceed the dynamic range of a BDA as the user moves from the end of the path to near the antenna.

Raising the Antenna as much as possible increases the distance to the user near the antenna and stabilizes RF levels over the whole coverage pattern.

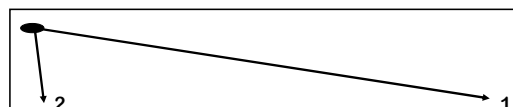
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IN-BUILDING ANTENNAS



LOW ANTENNA: #1 = 200' = -66 dB #2 = <20' = -46 dB
DYNAMIC RANGE = 20 dB

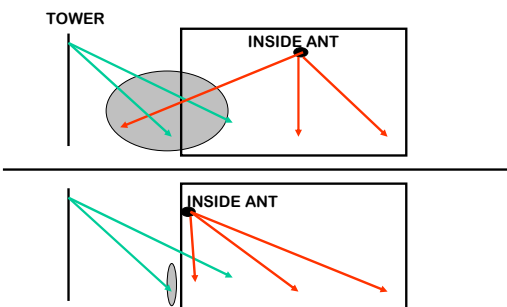


HIGH ANTENNA: #1 = 200' = -66 dB #2 = 40' = -52 dB
DYNAMIC RANGE = 14 dB

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WAVE FRONT REINFORCEMENT



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IN-BUILDING ANTENNAS

- Multiband : VHF + UHF + 800
- Low Profile : Garages, Tunnels, etc.
- Very low profile : Centaurian
- Indoor Panel
- Indoor Directional

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POWER DIVIDERS, COUPLERS AND TAPS

The old practice of using 50:50 power splitters to branch off a coax cable is an obsolete practice.

Different ratios are available that will better distribute even power levels.

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POWER DIVIDERS, COUPLERS AND TAPS

- Available in many different values, split ratios;
 - 3 dB = 50:50 % split
 - 4.8 dB = 33:67 % split
 - 6 dB = 25: 75 % split.
 - 10 dB = 10: 90 % split
 - 20 dB = 1: 99% split
- 2 way power splitting may be wasting RF power.
- Broadband and Harmonic Hybrid decouplers.
- Taps, impact on in-line losses:
 - 10 dB = 0.5 dB thru loss

NEVER USE "T" CONNECTORS AS SPLITTERS.

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RF-OVER-FIBER TECHNOLOGY

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Basic RF over Fiber Distribution Advantages

1. Lower installation costs compared to coax.
Materials
Routing
Haz Mat avoidance
2. Lower RF loss than coaxial cable:
Increases the area of coverage per BDA
Can feed distant buildings
3. Very Broadband:
Can be RF frequency insensitive.
Expansions easily accommodated.

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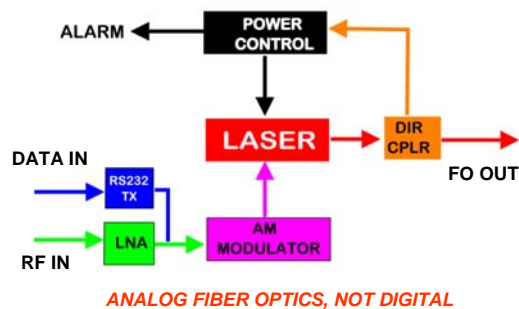
Definitions

1310 and 1550 nm:
Optical frequency in nanometers. 1310 and 1550 are the most common and economical for RF over Fiber circuits.

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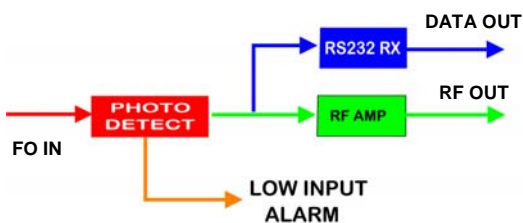
RF Over Fiber Basics: Transmitters



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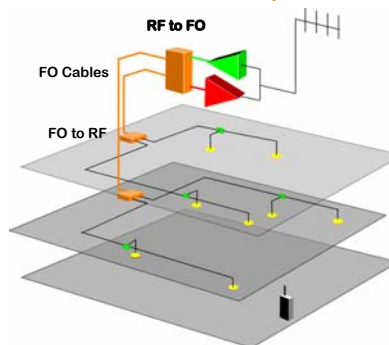
RF Over Fiber Basics: Receivers



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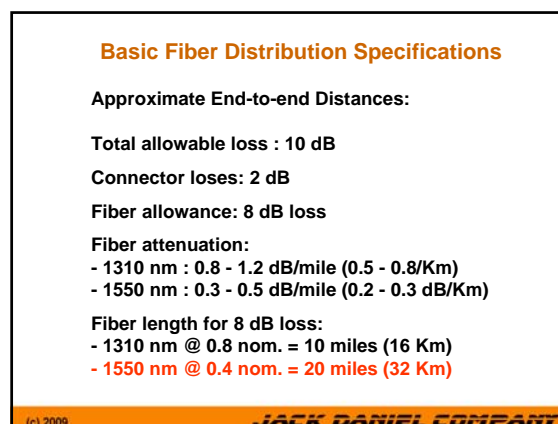
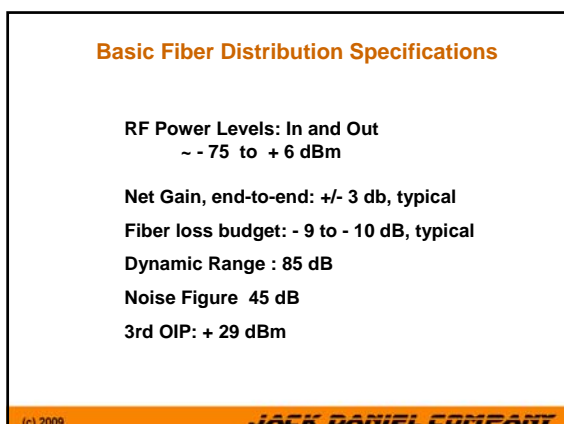
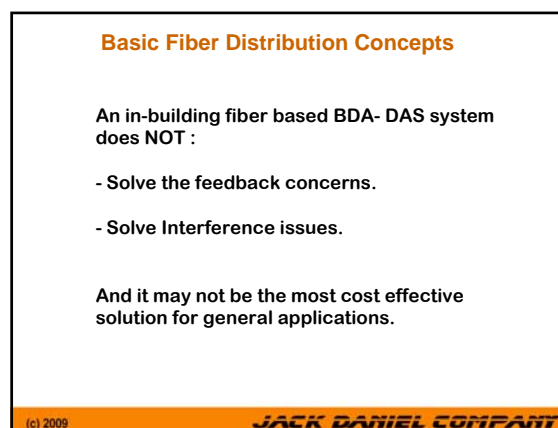
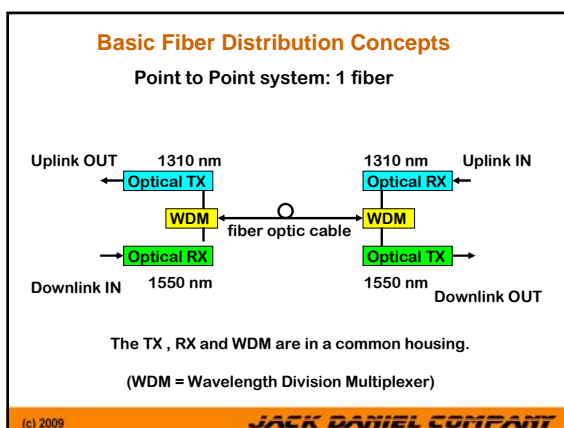
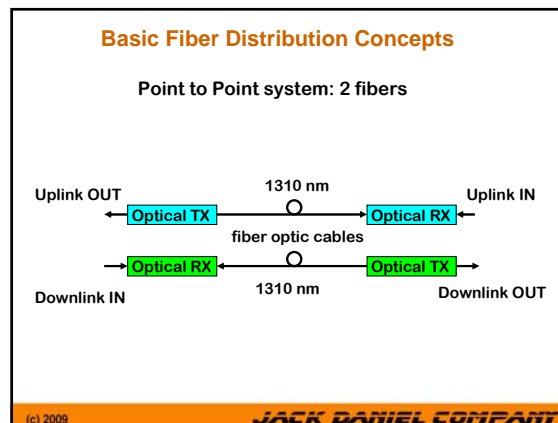
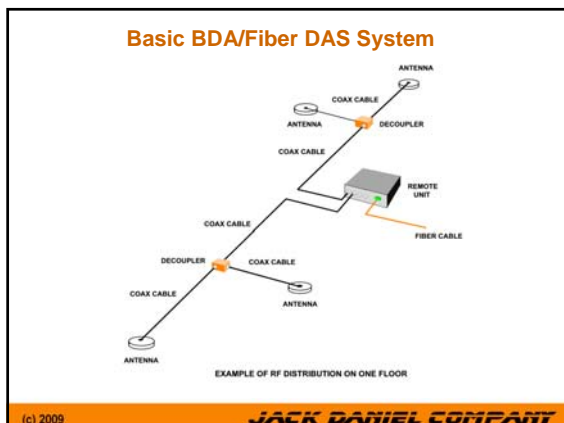
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Basic BDA/Fiber DAS System



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Basic Fiber Distribution Specifications

Propagation Delay has become an important Specification for simulcast and digital systems.

Fiber Delay: ~ 5 μ S/Km ~ 8 μ S/mile
(60% speed of light)

RF - Fiber Transceivers: ~ 5 μ S total, end-to-end.

Fiber transceivers have sub-microsecond delays, therefore the maximum fiber length that keeps delay less than 15 μ S is approximately 2miles.

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Basic Fiber Distribution Specifications

Fiber Optic Cables do NOT radiate RF.

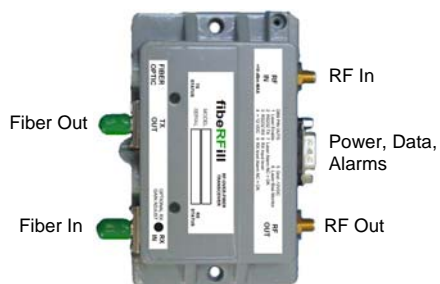
Single Mode type fiber is used in almost all RF over Fiber systems.

APC (Angle Polished Connectors) are always used and not mixed with any other type anywhere in the system.

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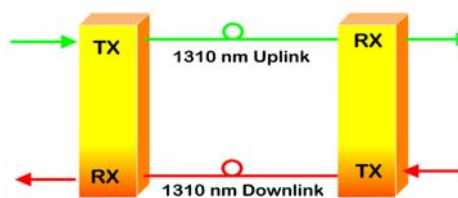
Basic RF Over Fiber Transceiver



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RF over Fiber Transceivers

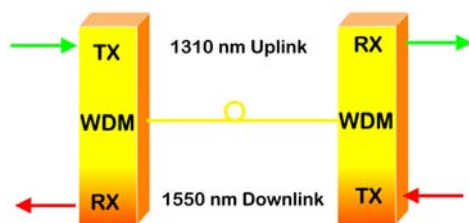


Most Common Arrangement
TX & RX may be in common case
Note: Can Use Same Optical Freq. Both ways.

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RF over Fiber Transceivers



Note: Different Optical TX Freq.s

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Fiber Distribution Components

Splice Tray
Protects Splices



Patch Panel
Protects Main Cable
Facilitates Testing



Splice Tray and Patch Panel can be one assembly

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RF over Fiber Distribution Connectors

Cable Connectors are always Males



SC-APC Type

FC-APC Type

Important Color Codes:

Cables: **Yellow** = SM / Orange = MM

Connectors Body: **Green** = APC / Blue = PC

ALWAYS USE SM CABLE!

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Multiple Transceiver Shelves

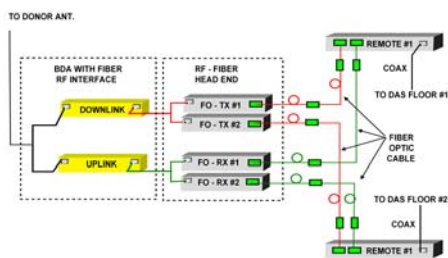


Head end unit: supports 1 to 5 remote units

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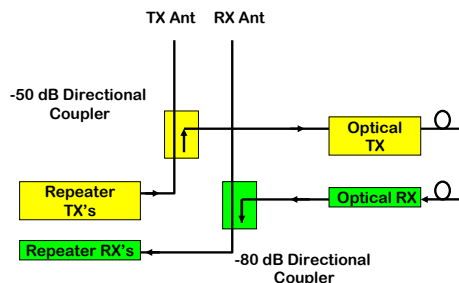
Multiple Transceiver System



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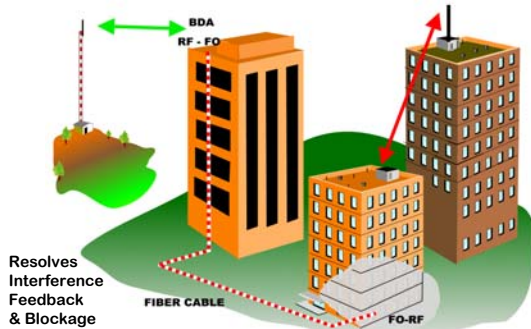
Direct To Donor Interface



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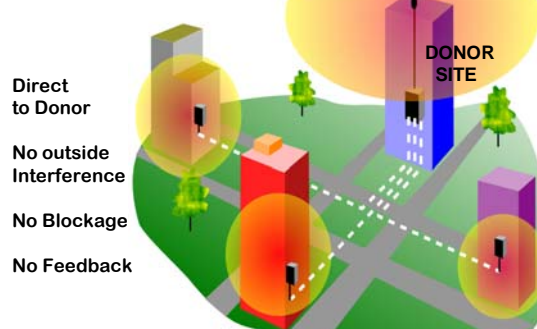
Special Systems: Remote BDA



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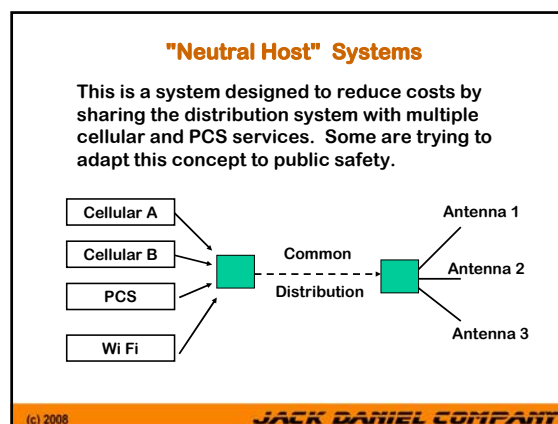
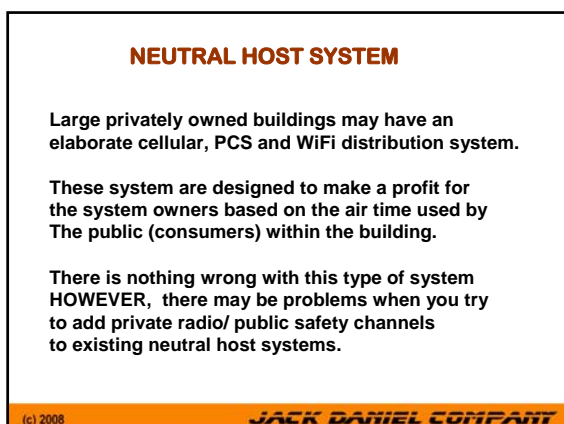
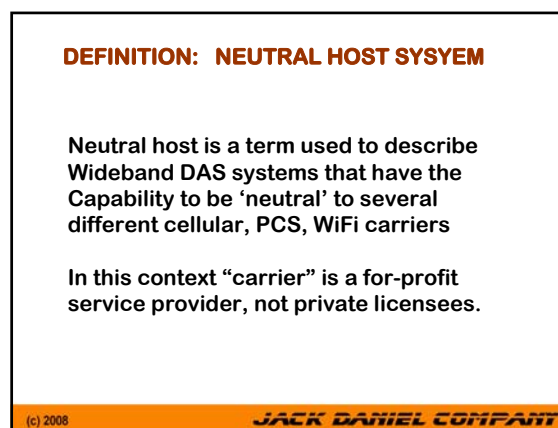
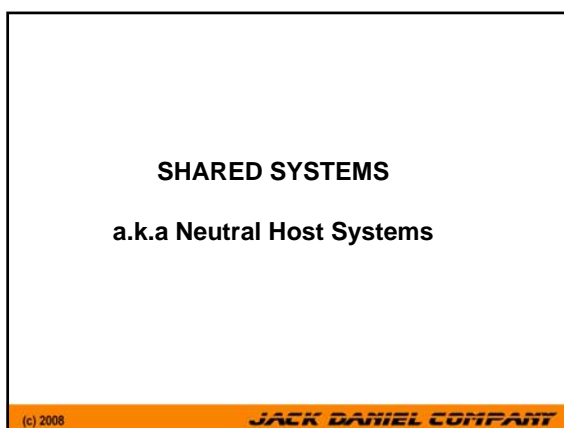
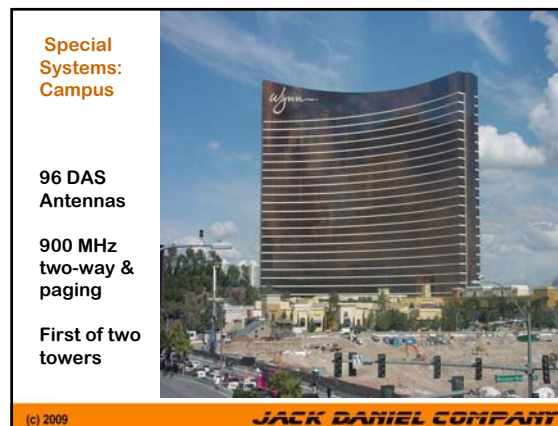
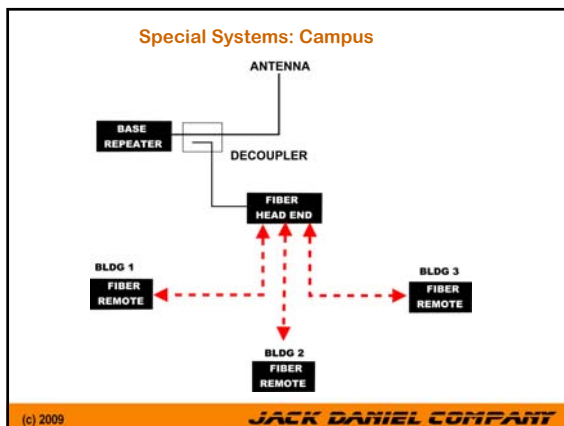
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Special Systems: Campus



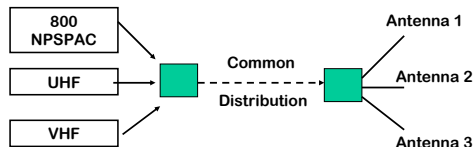
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"Neutral Host" Systems

Using this concept for Public Safety becomes more difficult when VHF and UHF channels are distributed.



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Neutral Host Priority : Profit

Basic Rule:

Use the minimum amount of equipment investment and cover the least amount of area that will provide The maximum income per investment dollar.

This means NOT having back-up power or covering areas where there is little routine public travel.

After hours maintenance is not required or offered. Tomorrow is considered good repair service for Consumers.

System can be altered to make more profit.

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Mission Critical Priorities

Basic Public Safety Rule: Providing life critical coverage is more Important than costs.

Coverage is needed where first responders, employees and the public go, including emergencies.

Reliability and survivability requires power back-up, Redundancy, and public safety grade equipment.

Serviceability includes 27/7 access to the system. the ability to alter the system in an emergency and pre-incident fault monitoring.

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Technical Incompatibilities

The way cellular systems operate is much different than public safety radio systems.

Cellular has relatively low power handsets and Some 'drop-outs' are accepted.

Public safety handsets are much more powerful and can overload a system designed for cellular.

Overloading can generate interference (IM), distortion and loss of data.

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Technical Incompatibilities

The frequencies used can interact.

For example, the high end of NPSPAC channels are immediately adjacent to Cellular A band and parallel signal boosters will disrupt both systems.

After 800 rebanding there will be interaction between Cellular B and public safety.

Filters in cellular signal boosters are lower performance than those used in public safety rated signal boosters. (That's one reason consumer grade cellular boosters are cheaper)

Combinations of the two bands can generate destructive intermodulation.

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Operational Incompatibilities

Mission Critical users on shared systems should:

- Be aware of system accessibility. A Shared system may require coordination and approval of multiple carriers, building owners, etc. Access may take days or weeks.
- System coverage maintenance. Cellular engineers may change coverage to meet their needs without notification or agreement with the non-cellular user, losing critical non-cellular coverage.
- In an extreme situation, the mission critical user should be able to shut down the system when it causes interference.

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Common "Neutral Host" Systems

The majority of new Neutral Host systems use fiber distribution because of the bandwidth.

When industrial and/or public safety channels are required, it is becoming best practice to install a separate DAS system at the same time.

Separate DAS system antennas are spaced 50' or more apart.

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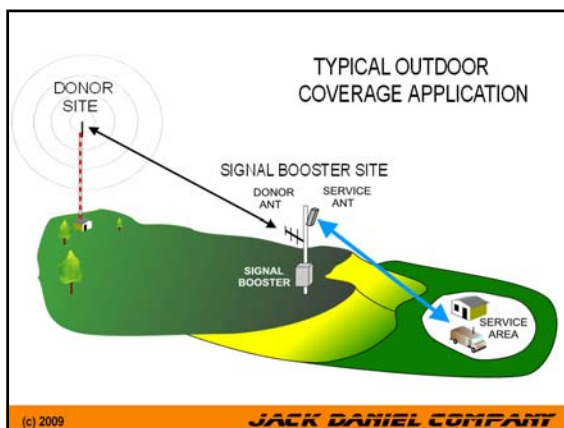
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Outdoor Fill-In Coverage

Remember: Signal Boosters may NOT be used to extend coverage legally.

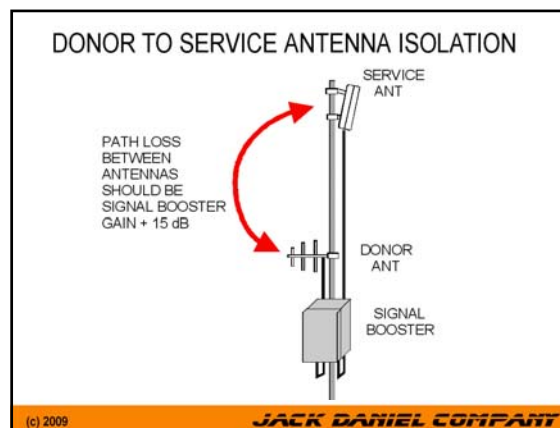
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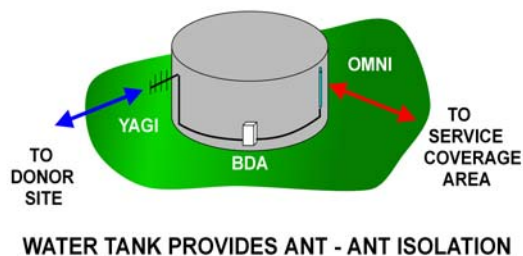
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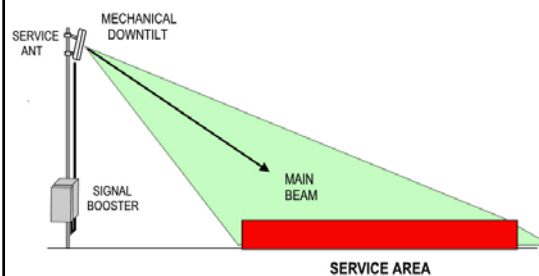
OUTDOOR COVERAGE ANTENNA ISOLATION



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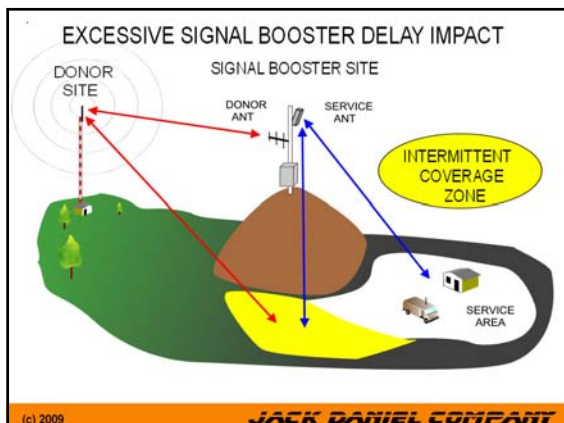
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BEST PRACTICES Fill-In Coverage Optimization



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BEST PRACTICES : FILL-IN COVERAGE

- Use Directional antennas for better vertical antenna-to-antenna isolation.
- Control service area antenna pattern to reduce out of area signals.
- When using Class A (channelized) signal boosters, propagation delay differential in coverage overlap zones can be excessive. Differential delays over 15 uS can be problematic.
- Use minimum gain and minimum output power to obtain antenna – antenna isolation.

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FCC RULES FOR PART 90 LICENSEES

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What is a Signal Booster (BDA) ?

- A Signal Booster is a highly specialized R.F. Amplifier designed to boost weak radio signals and distribute radio signals within an otherwise obstructed area of coverage.
- FCC Rules (90.219) allow Part 90 licenses to use Signal Booster without additional licensing, subject to certain conditions.

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FCC Rule Summary : Part 1

The FCC has two classes of Signal Boosters;

Class A: Commonly called Channelized or channel selective.

Class B: Commonly called Broadband or band selective.

ALL signal boosters used in Part 90 must be FCC certified.

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FCC Rule Summary : Part 2

1. Only users with FCC licenses are authorized to use signal boosters.
2. The maximum output power under this rule is 5 watts ERP. Higher power must be licensed as a station.
3. Mobile signal boosters are NOT authorized.
4. Signal Boosters are 'secondary' use and must not cause interference.

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**Codes and Ordinances
Used to Provide In-Building
Wireless Communications
For Public Safety Agencies
within Privately Owned
Structures.**

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Local Ordinances and Codes requiring In-Building coverage is no longer unusual.

An estimated 200 jurisdictions have some form of local requirement with more under development.

As a result, de facto standards are being established and nation wide codes are not too distant in the future

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Jurisdictions with Local Signal Booster Codes

- | | |
|-----------------------------|-----------------------|
| - City of Burbank | - City of Folsom |
| - City of Roseville CA | - City of Ontario |
| - City of Scottsdale AZ | - City of Tempe AZ |
| - City of Ft. Lauderdale FL | - Grapevine TX |
| - Hampshire (Illinois) FPD | - City of Sparks NV |
| - City of Broomfield CO | - City of Boston MA |
| - City of West Hartford CT | - City of Irvine CA |
| - City/County of Sacramento | - City of Tempe AZ |
| - City of Riverside CA | - Sarpy County NE |
| - City of Sparks NV | - City of Glendale CA |
| - Mercer Island WA | - City of San Jose CA |
| - Muskego WI | - Richmond VA |

and more

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National In-Building Code Developments

Driver:

NIST Post 9-11 WTC report Recommendation # 22;

Installation, inspection and testing ofradio communications....: (1) are effective for large scale emergencies in buildings with challenging radio frequency propagation environments.

This report, and other factors such as fire responders input, are driving rapid efforts towards common, nationwide in-building communications standards.

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National Fire Protection Association (NFPA)

- NFPA has developed national in-building codes.
- Codes enable local adoption and uniformity.
- Nationwide impact
- Signal booster hardware to meet minimum standards and operational specifications.
- Primary fire codes effected: NFPA-1 and NFPA 72
- Compatible with IFC codes (next slide)

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International Code Council (ICC)

- These new codes appear as International Fire Code (IFC)
- These codes are the primary fire code for almost every city in the U.S.
- Signal booster hardware to meet minimum standards and specifications.
- Compatible with NFPA code.
- Code effected: New IFC Section 511 and Appendix I.

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New Code Provisions

- 12 hour battery or local generator backup.

- Non-interference.

Other in-building wireless systems cannot degrade public safety communications.

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Newer Code Provisions

Qualified design and installation personnel

- Must be certified by the equipment manufacturer or some recognized authority, subject to the agencies approval.

Prequalified equipment manufacturers

- Must meet tighter technical specifications.

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New Code Provisions

Public Safety Frequency changes, expansions.

- Owner is advised public safety spectrum changes may occur over time due to FCC rule changes and the public safety in-building system must be modified or replaced as required.

Notable examples are;

- 800 MHz 'rebanding'. Shifts many 800 MHz public safety frequencies.
- New 700 MHz public safety channels. Will be added eventually to almost every urban public safety system.

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New Code Provisions

NFPA code: alarms sent to local fire panel:

- Amplifier failure.
- AC power failure.
- DC power failure.
- Antenna circuit failure.

Optional Remote Access Capability:

- Pager alert of failure or oscillation.
- Dial-up control.
- Intranet/Internet control and alarms.
- Remote adjustments.

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Costs to Private Property Owners

Exact costs are dependent upon many variables; size and type of structure, frequencies required, local electrical/union codes, etc.

The Building Owners and Managers Association (BOMA) recently cited costs up to \$1.50/sq ft. These are usually neutral host type systems.

More typically, public safety only system costs range down to as low as \$0.25 per square foot.

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National Public Safety Telecommunications Council (NPSTC)

This group is NOT writing codes, but has issued an In-building "Best Practices" White paper last fall.

The NPSTC paper reflects much of the new code requirements and endorses the efforts of NFPA and ICC.

The NPSTC paper is widely accepted within the Public Safety community and by others, such as federal groups.

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Additional Resources.....

- FCC : www.fcc.gov
- National Fire Protection Association (NFPA)
www.NFPA.org
- International Code Committee (ICC)
www.ICCsafe.org
- National Public Safety Telecommunications Council
www.NPSTC.org
- Free material available from Jack Daniel Company
www.RFSolutions.com:
 - * 40 + On-line local code examples
 - * In-Building code white paper
 - * Model universal in-building code
 - * Signal booster educational material

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Thank You

Jack Daniel, member;
APCO International
NFPA In-Building Code task force
ICC In-Building Code task force
Vice-Chair, NPSTC In-Building committee

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