Implementing Digital Wireless Systems

And an FCC update

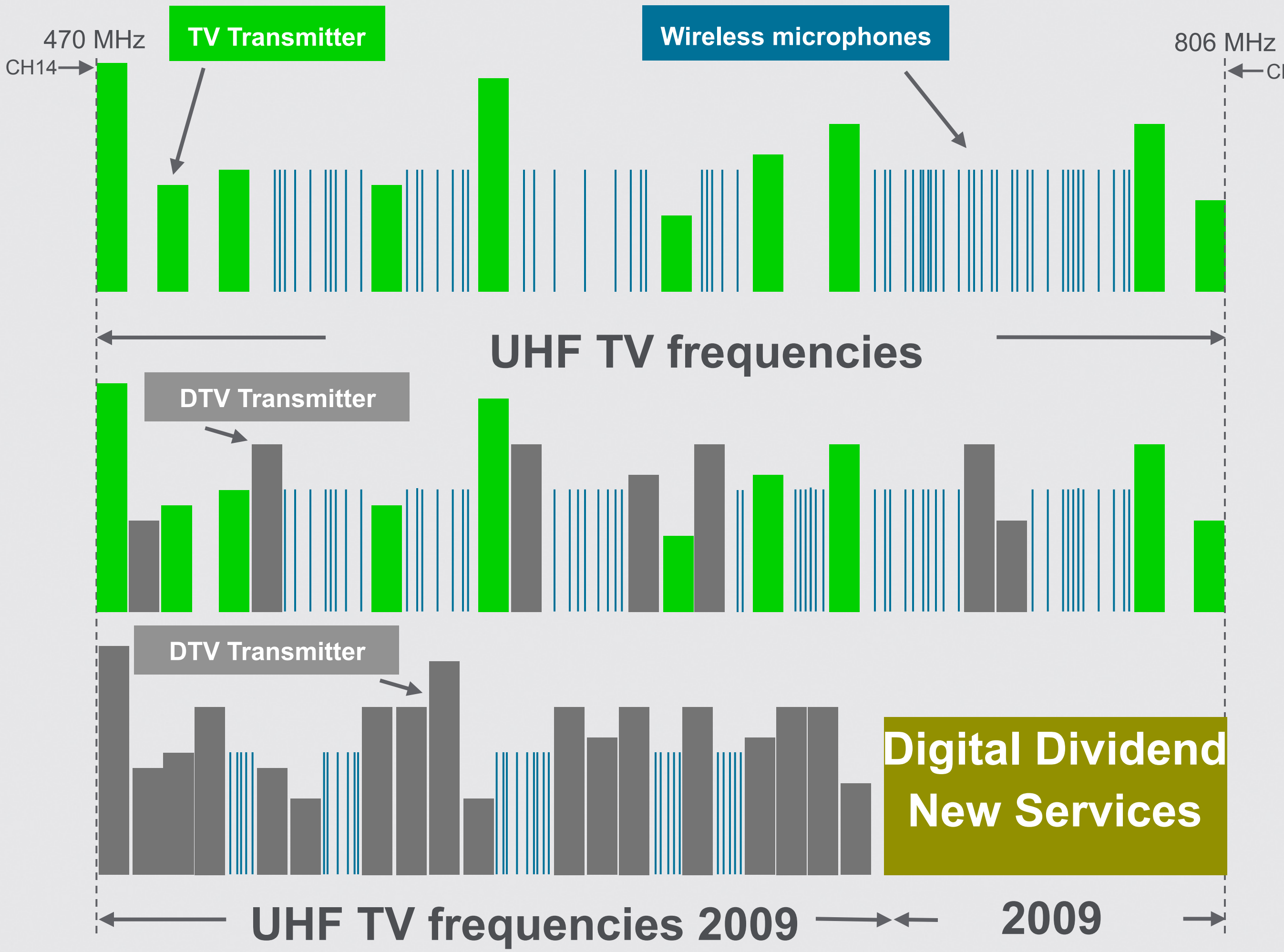
Spectrum Repacking

Here We Go Again:

The FCC is reallocating 600 MHz

Frequencies for Wireless Mics

30 - 45 MHz (8-m HF)	Antenna length ; RF-interference from (electric) appliances
174 - 250 MHz (VHF)	Good wave propagation; TV-transmitters; RF-distortions from digital equipment
450 - 960 MHz (UHF)	wide frequency range good wave propagation
2400 - 2485 MHz (ISM) IndustrialScientificMedical	poor wave propagation ; no exclusive frequencies (license free devices); interference from microwave-ovens



Yesterday:

Analog TV only

Transition:

Analog & DTV

Now:

Full Digital Scenario

White Space Devices (WSD) aka TV Band Devices (TVBD)

"White Space" channels 2 - 51 are open to unlicensed devices:

- Rural broadband internet
- Metropolitan broadband internet
- Multimedia services
- Home networking systems
- Consumer electronics: tablets, computers, media servers and cell phones w/ advanced features
- Future products

Safeguards For Wireless Mics

FCC rules governing WSD include safeguards to avoid interference to wireless microphones:

- Reserved channels: 2 channels in each market are reserved for wireless mics
- WSD must use Geolocation/Database system or Spectrum Sensing (further in the future) to find channels that are not reserved for TV or by wireless mic operators

FCC Established Unlicensed Class

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Licensed

- Priority over unlicensed operation
- Can operate up to 250mW in UHF band.
- Direct access to reserve channels on the database system
- Broadcasters, cable TV operators, film and content providers are eligible to obtain a license.

Unlicensed

- Limited to 50mW in both VHF *and* UHF
- No recourse if interference is experienced.
- Must make a request to the FCC to reserve additional channels in the database

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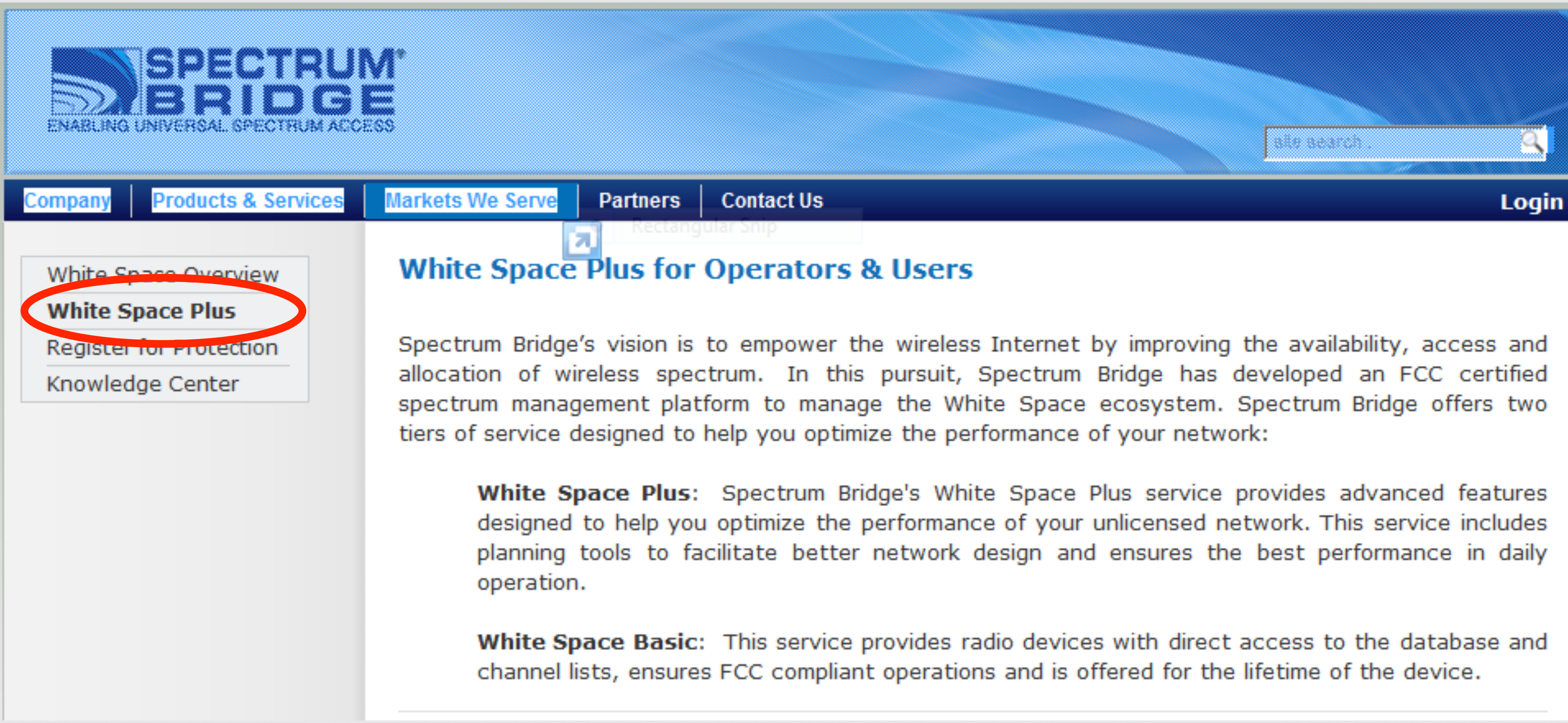
Licensed mic operators have direct access to reserve additional channels



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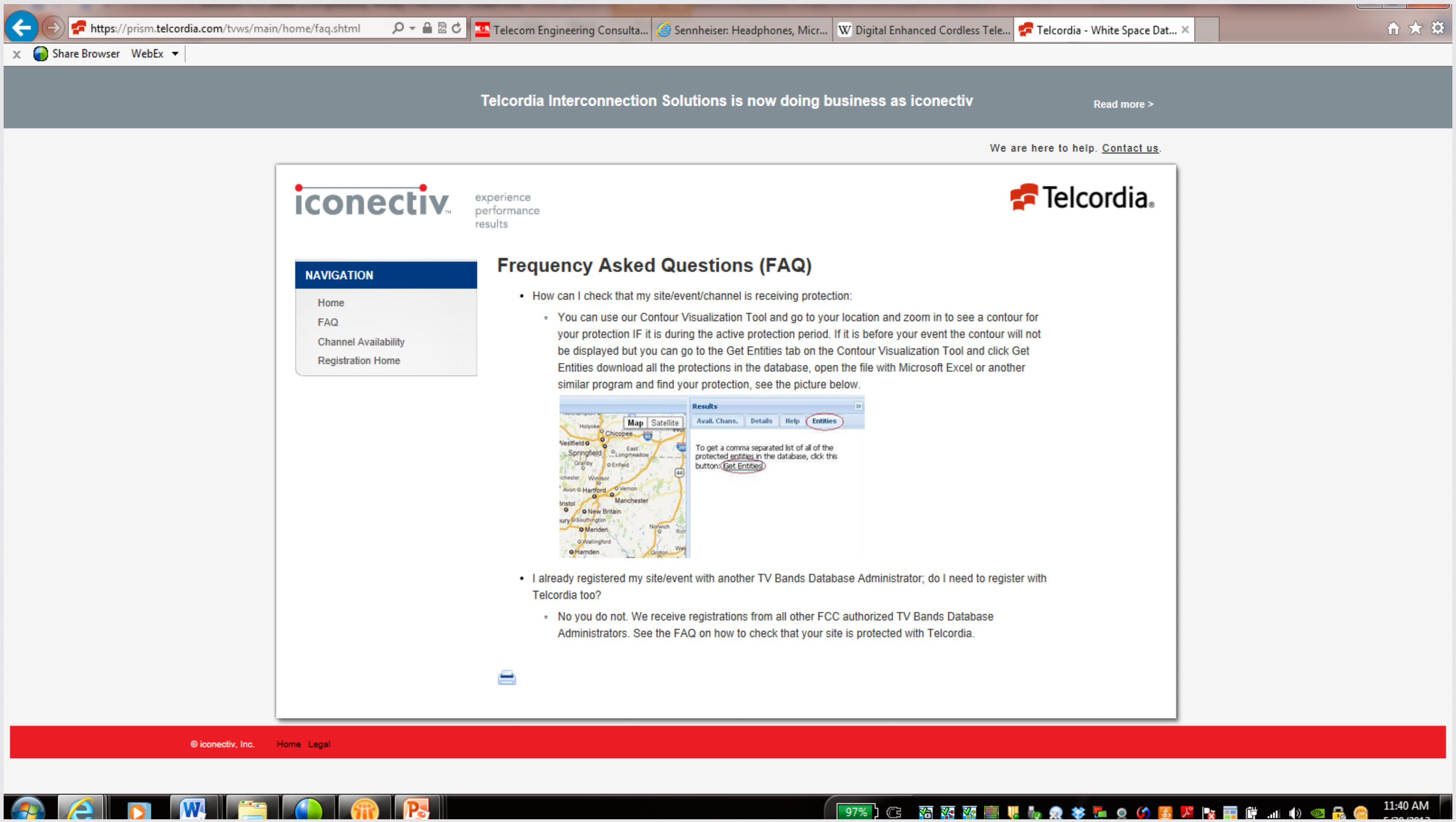
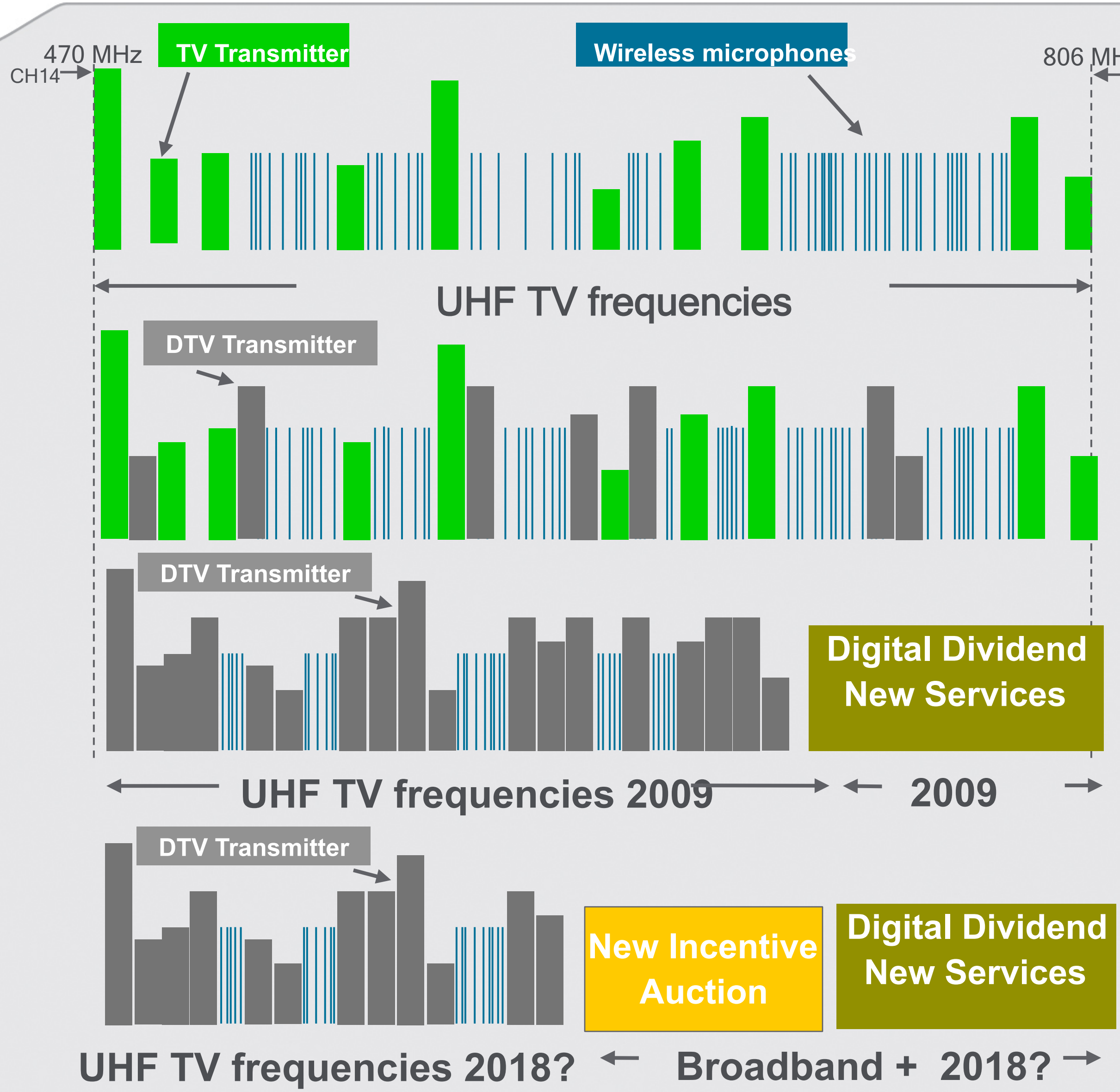
Licensed mic operators have direct access to reserve additional channels





~20 years ago:

Analog TV only

Transition:

Analog & DTV

Now:

Full Digital Scenario

Future:

More Broadband services

Two Pending FCC Actions

The primary issues are

1) Incentive Auctions

Basically a reallocation of the 600 MHz band, similar to the 700 MHz reallocation that occurred a couple of years ago.

2) Expanding eligibility for licensed operation

This is potentially good for non-broadcast professional users such as Broadway and major touring productions.

The Current Schedule and Incentives

FCC presented the auctions as a unique business opportunity for broadcasters because the broadcasters will share in the proceeds of the auction.

- Options for Broadcasters for reverse auction. Each option will have its own monetary incentive depending on market, spectrum, etc.:

    1. Give up your channel by participating in the reverse auction
    2. Move to VHF
    5. Share channel
    6. Accept additional interference
    7. TBD (Public suggestions are being considered)

The Current Schedule and Incentives

Order and Report will be finalized in 2013.

Bidding and repacking auction scheduled for June 2014, afterwards payments and licensing will take place.

How long before operators may have to vacant the 600 MHz band?
Probably at least: 5 years

What Is Sennheiser Doing?

Sound Academy

Communicating

&

Innovating

Before the
Federal Communications Commission
Washington DC 20554

In the Matter of	)	
	)	
Expanding the Economic and Innovation	)	Docket No. 12-268
Opportunities of Spectrum Through	)	
Incentive Auctions	)	

COMMENTS OF
SENNHEISER ELECTRONIC CORPORATION

Sennheiser Electronic Corporation responds to the Notice of Proposed Rulemaking released on October 2, 2012, in the above-captioned proceeding.[1] Sennheiser is also filing

Digital Wireless Systems

Digital

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Why the push for digital?

The promise and potential advantages of converting the natively analog audio signal to digital data prior to transmission can be summarized to:

- Better and more consistent audio quality.
- Transmission of digital data allows for increased information capacity within comparable bandwidth (= better spectrum efficiency).
- Transmission security (encryption).
- Superior immunity to interference.
- Additional features through software/firmware updates.

The main driving force remains BEST POSSIBLE AUDIO QUALITY !
(S/N, frequency response, immunity to interference)

What is Modulation?

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To transmit a signal (over the air) requires 3 main processes:

1. Generation of a pure carrier.
2. Modulation of that carrier with the information to be transmitted. Any reliably detectable change in carrier characteristic could carry information!
3. Detection at the receiver of the signal modification in the transmitter and reconstruction of the information, also known as demodulation.

What is Modulation?

There are only three characteristics of a carrier signal that can be modified over time to convey information:

- Amplitude,
- Phase, or
- Frequency.

(Actually, make that two: Phase and frequency are just different ways to view or measure the same signal change!)

Technically ‘Digital Modulation’ is a misnomer and refers to an analog carrier modulated with digital data (digital representation of an audio signal).

Any modulation always changes the analog properties of the carrier.

Analog (Scalar) Modulation

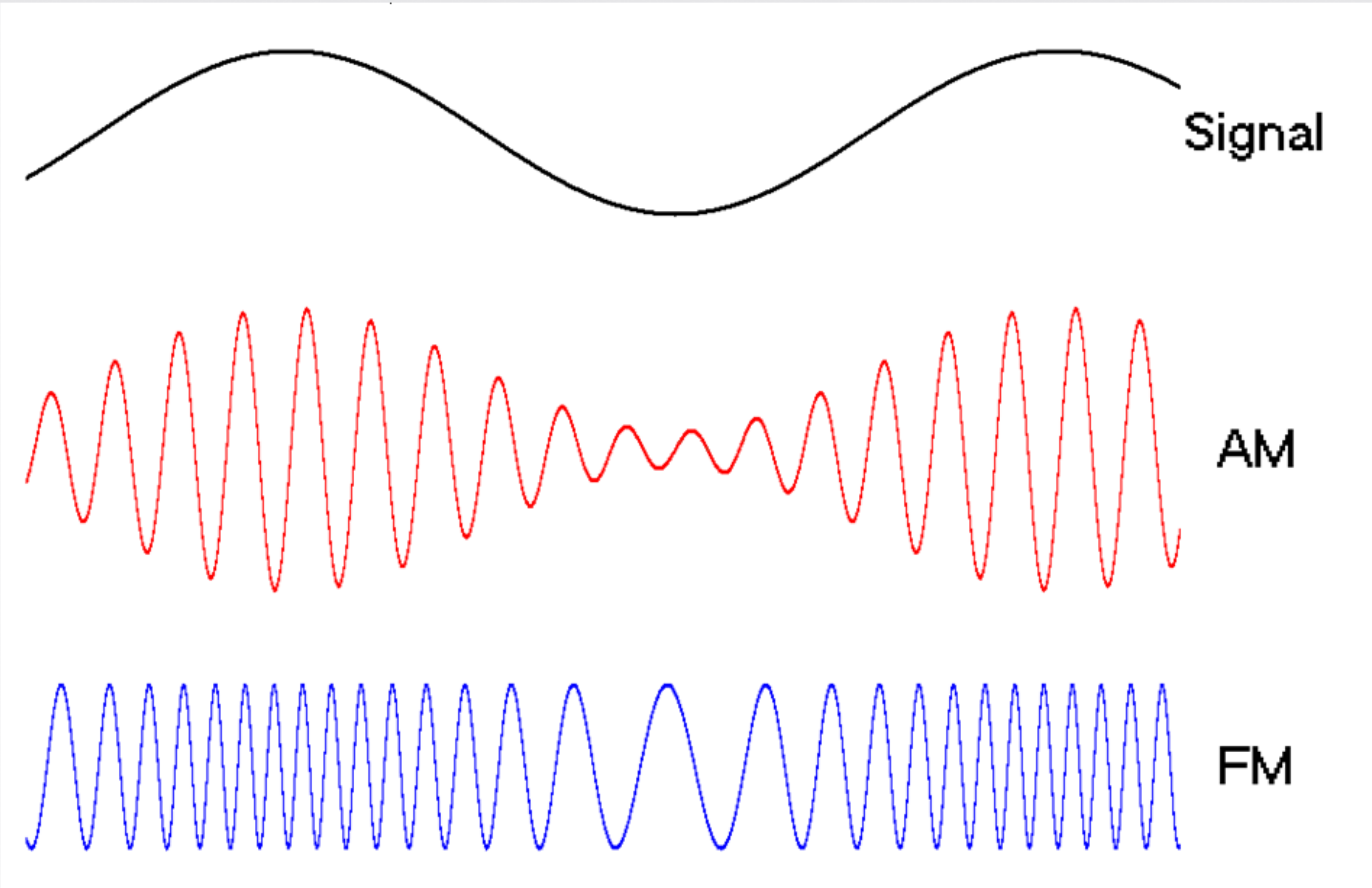
Amplitude Modulation (AM): In AM the frequency of the carrier is kept constant and its amplitude is changed in proportion to the instantaneous amplitude of the modulating message signal.

- min. required BW = 2*AF_{max}
- max. S/N ≈ 30 dB_A (affected by fading)
- AF response limited by occupied BW

Frequency Modulation (FM): In FM the amplitude of the modulated carrier is kept constant, while the frequency is varied in proportion to the instantaneous amplitude of the modulating message signal.

- min. required BW = 2*(Df + AF_{max})
- max. S/N ≈ 50 dB_A (for typ. Df = ±50 kHz w.o. AF processing - ≥100 dB w. dyn. processing and RF signal strength at Rx > -80 dBm)
- AF response dependent on BW

Analog Modulation



Digital Modulation

- With analog modulation systems, the information signal is analog.
- With digital modulation, the information signal is digital.

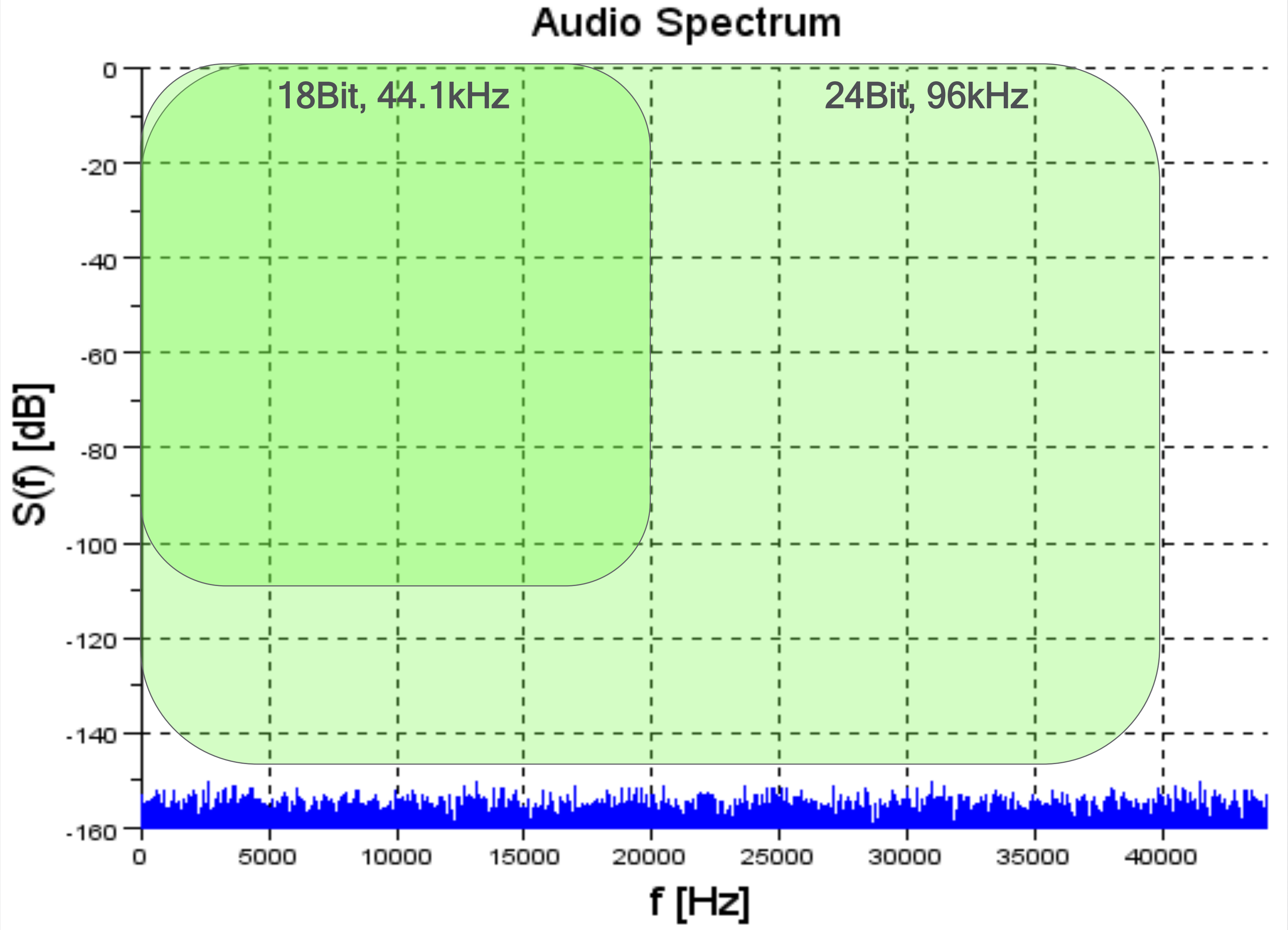
- Either system uses analog carriers!

Digital Audio Representation

In order to achieve superior audio quality we strive for a frequency response up to 20 kHz and a dynamic range (S/N) of >108 dB.

- This minimum requirement can be achieved with an A-to-D conversion of 18 bits with a sampling rate of 44.1 kHz, resulting in a bit rate of 793.4 kBit/sec.
- Technically possible today is an A-to-D conversion with 24 bit at a sampling rate of 96 kHz, resulting in a bit rate of 2.304 MBit/sec.
- To facilitate reliable transmission additional data is required for framing and coding, expanding the data rate typically by a factor of ≈ 1.5 and resulting in gross bit rates of 1,2 MBit/sec and 3.45 MBit/sec respectively.

Digitized Audio



The Challenge of Digital Audio Transmission

Regulations for wireless microphones operating in the UHF frequency range limit the maximum occupied BW to 200 kHz!

At first glance attempting to transmit high quality digital audio (data rate of 1.2 MBit/s) through this narrow BW (200 kHz) looks like shoveling 1.2 tons of ……… into a 200 pound bag…

One possible option could be some processing of the digital data to result in significant data reduction or compression. Any such data processing may affect the ultimate audio quality and possibly introduce additional processing delays ('latency').

The Challenge of Digital Audio Transmission

One possible solution to meet the challenge of transmitting uncompressed high quality audio is through Quadrature Amplitude Modulation (QAM):

The advantage of QAM is that it is a higher order form of modulation and as a result it is able to carry more bits of information per symbol. By selecting a higher order format of QAM, the data rate of a link can be increased.

The table below gives a summary of the bit rates of different forms of QAM and PSK(Phase-Shift Keying).

The Challenge of Digital Audio Transmission

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- Modulation type determines number of bits per symbol

- BPSK	1 bit/symbol	(Binary Phase Shift-Keying)
- DBPSK	1 bit/symbol	(Differential Binary Phase Shift-Keying)
- QPSK	2 bit/symbol	(Quadrature Phase Shift-Keying)
- DQPSK	2 bit/symbol	(Differential Quadrature Phase Shift-Keying)
- 8PSK	3 bit/symbol	
- 16QAM	4 bit/symbol	(Quadrature Amplitude Modulation)
- 64QAM	6 bit/symbol	
- 256QAM	8 bit/symbol	

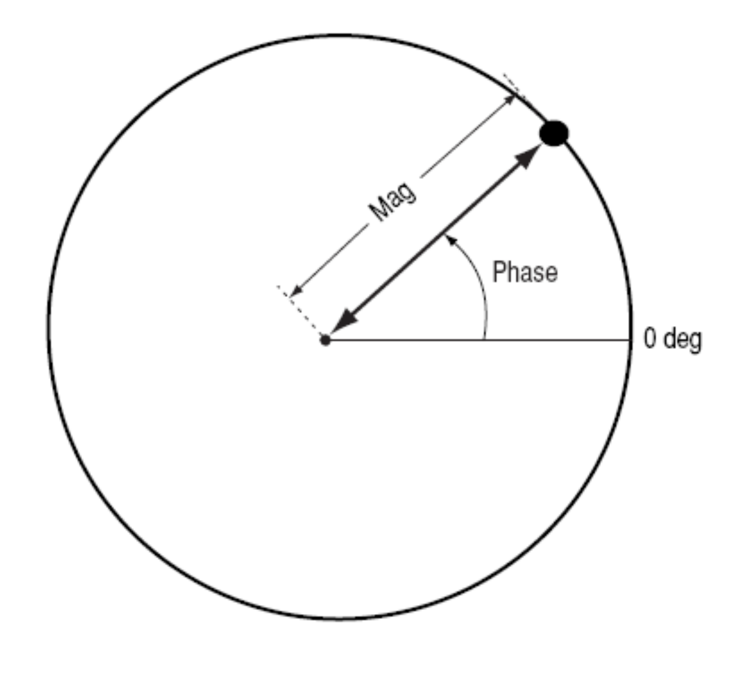
- For a fixed symbol rate, having more bits will provide a faster transfer rate

Simple modulation schemes like FSK, PSK, ASK offer only a fraction of the needed data rate within the permissible bandwidth.
(typ. ≤ 150 - 200 kbit/s)

Digital (Vector) Modulation

PSK

Although phase modulation is used occasionally for some analogue transmissions, it is far more widely used as a digital form of modulation where it switches between different phases. This is known as phase shift keying, PSK, and there are many flavors of this. It is also possible to combine phase shift keying and amplitude keying in a form of vector modulation known as Quadrature Amplitude Modulation.

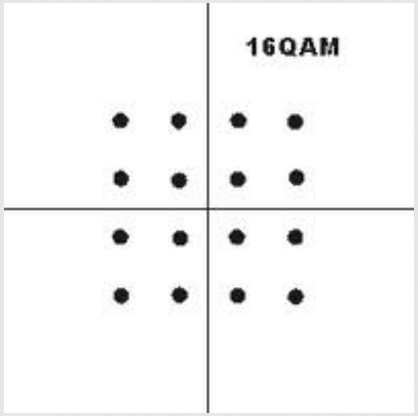


QAM

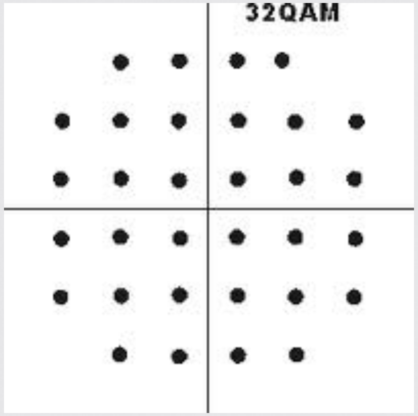
QAM is commonly generated as a signal in which two carriers shifted in phase by 90° are modulated. The resultant sum output includes both magnitude and phase variations.
A simple way to visualize specific conditions of magnitude and phase is made possible with polar diagrams.

Constellation Diagrams for QAM

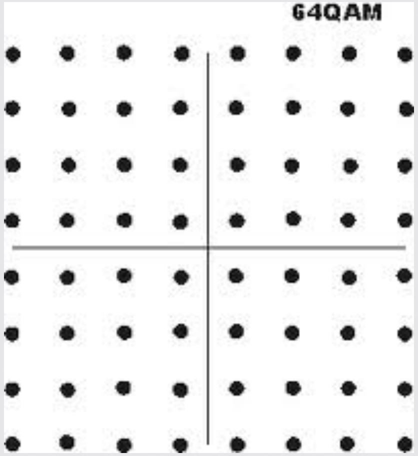
Constellation diagrams show the different positions for the end points of the vectors from corresponding polar diagrams. Shown here are representations for different forms of Quadrature Amplitude Modulation (QAM). As the order of the modulation increases, so does the number of points (CP) on the QAM constellation diagrams.



4 bits/symbol (2^4 CPs)



5 bits/symbol (2^5 CPs)



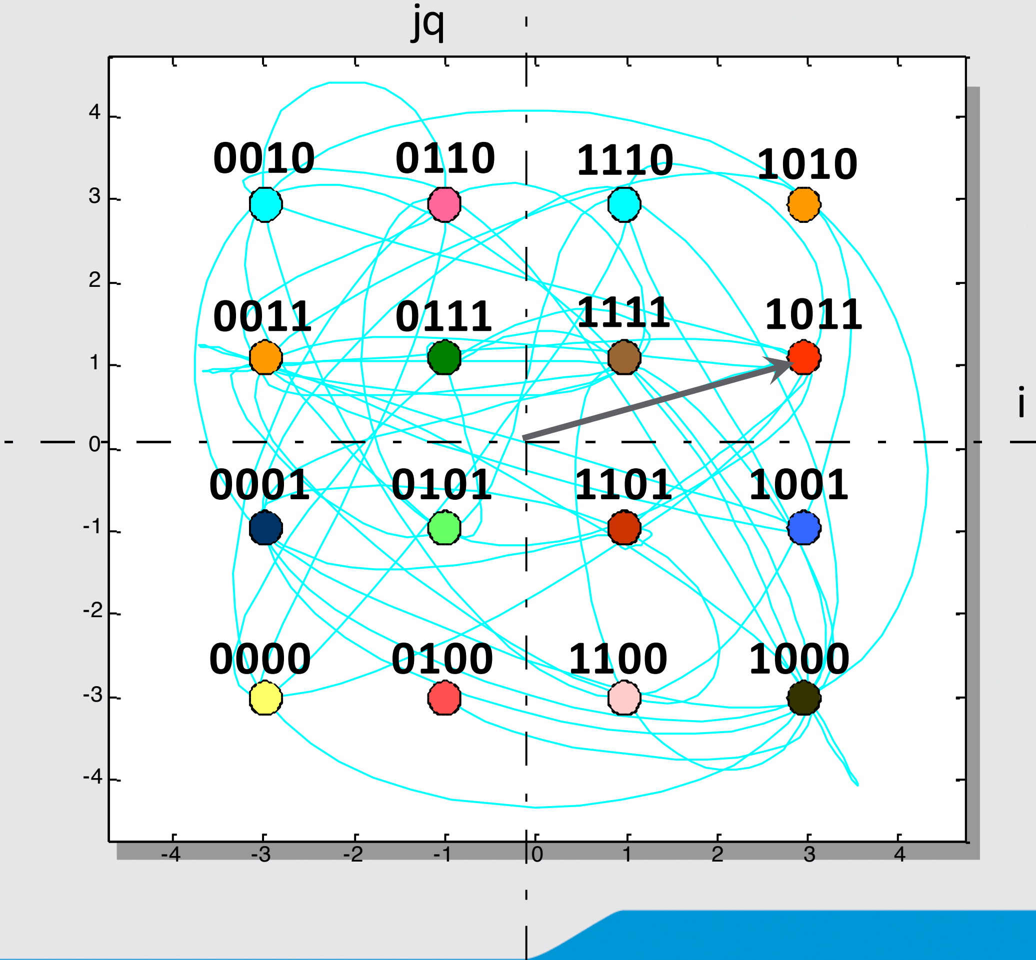
6 bits/symbol (2^6 CPs)

16 QAM

Discrete Amplitude and Phase Constellation Points (CP) are defined to represent a certain Bit(-sequence

Number of CPs/Symbols per Second is limited by given RF Bandwidth

The modulated RF Carrier (Vector) goes continuously from one to the other Constellation Point depending on Bit sequence to be sent



The Challenge of Digital Audio Transmission

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Higher order modulation rates are able to offer much faster data rates and higher levels of spectral efficiency for the radio communications system, this comes at a price. The higher order modulation schemes are considerably less resilient to noise and interference. In consequence this requires:

- higher carrier-to-noise and carrier-to-interference ratio at the receiver (CNR/CIR) resulting in the need for more transmit power;
- very accurate modulation with effective carrier and sideband suppression;
- extremely high linearity in all stages of the transmitter and receiver chains;
- great efforts to be applied to carrier and symbol recovery.

What does this mean for system design?

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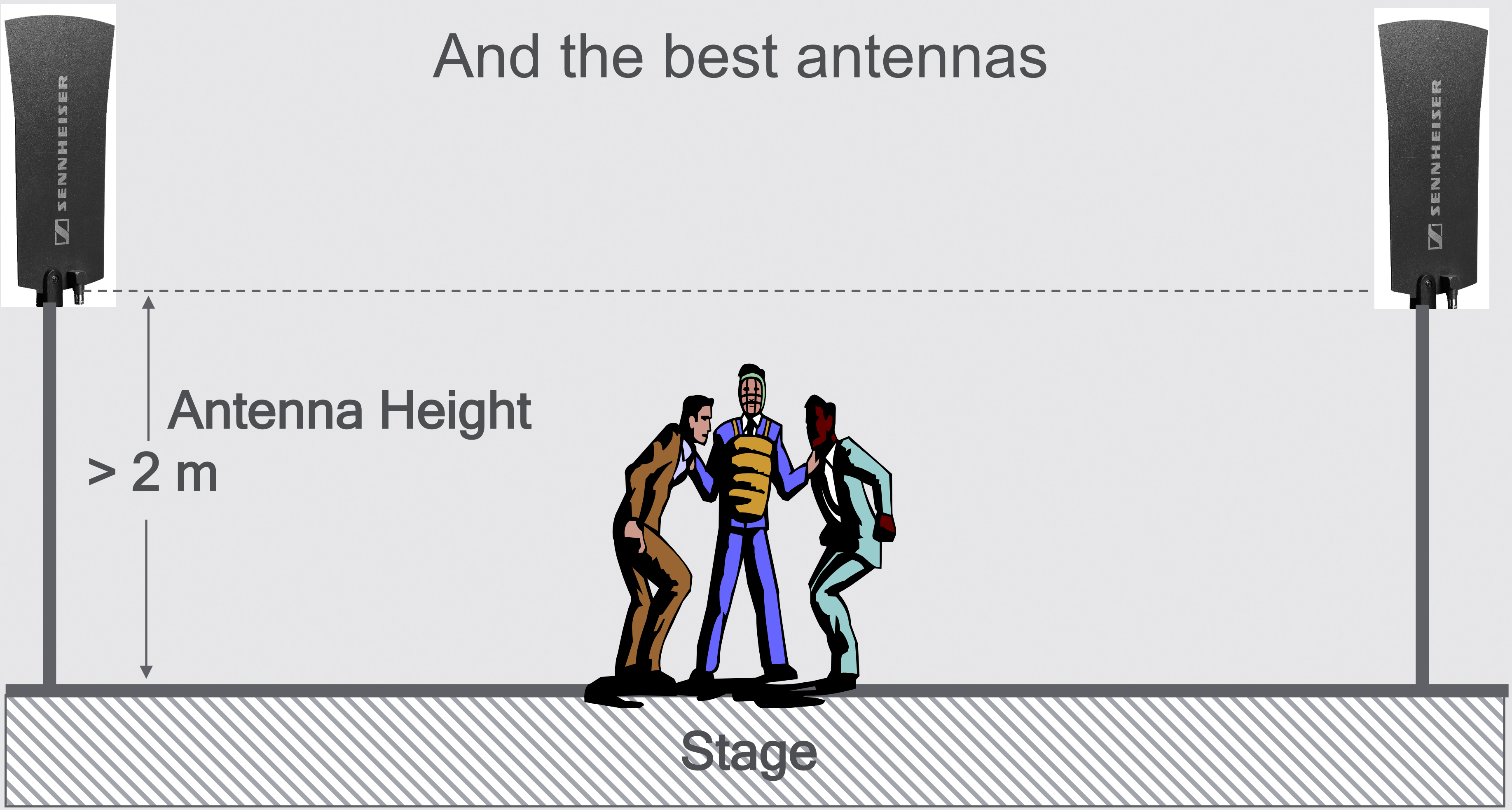
We still want best antenna postion

And the best antennas

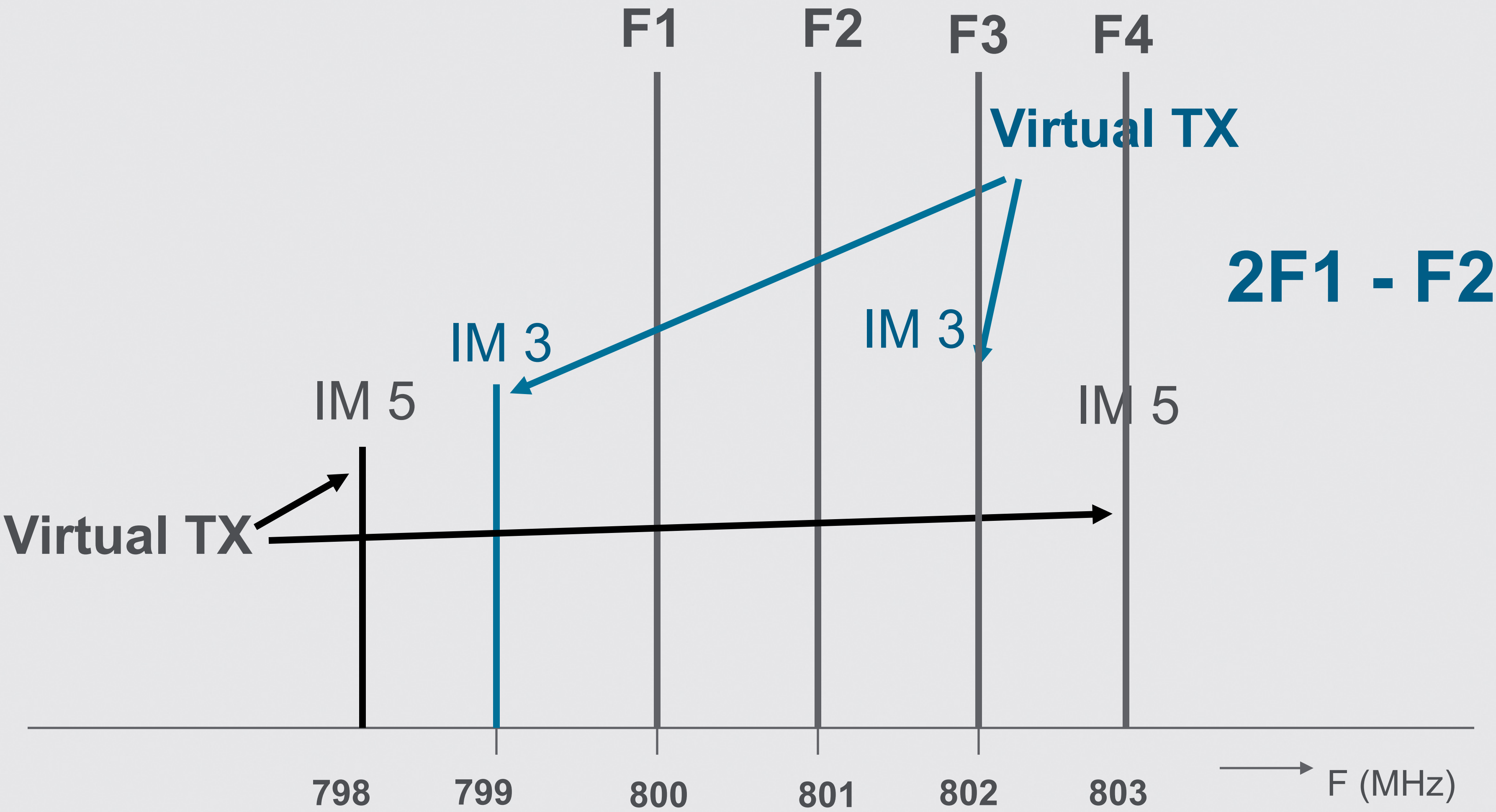


Benefits of Digital Transmission for System Design

Exact preservation of amplitude and phase information does demand highly linear circuits and precision timing. (complex circuits).

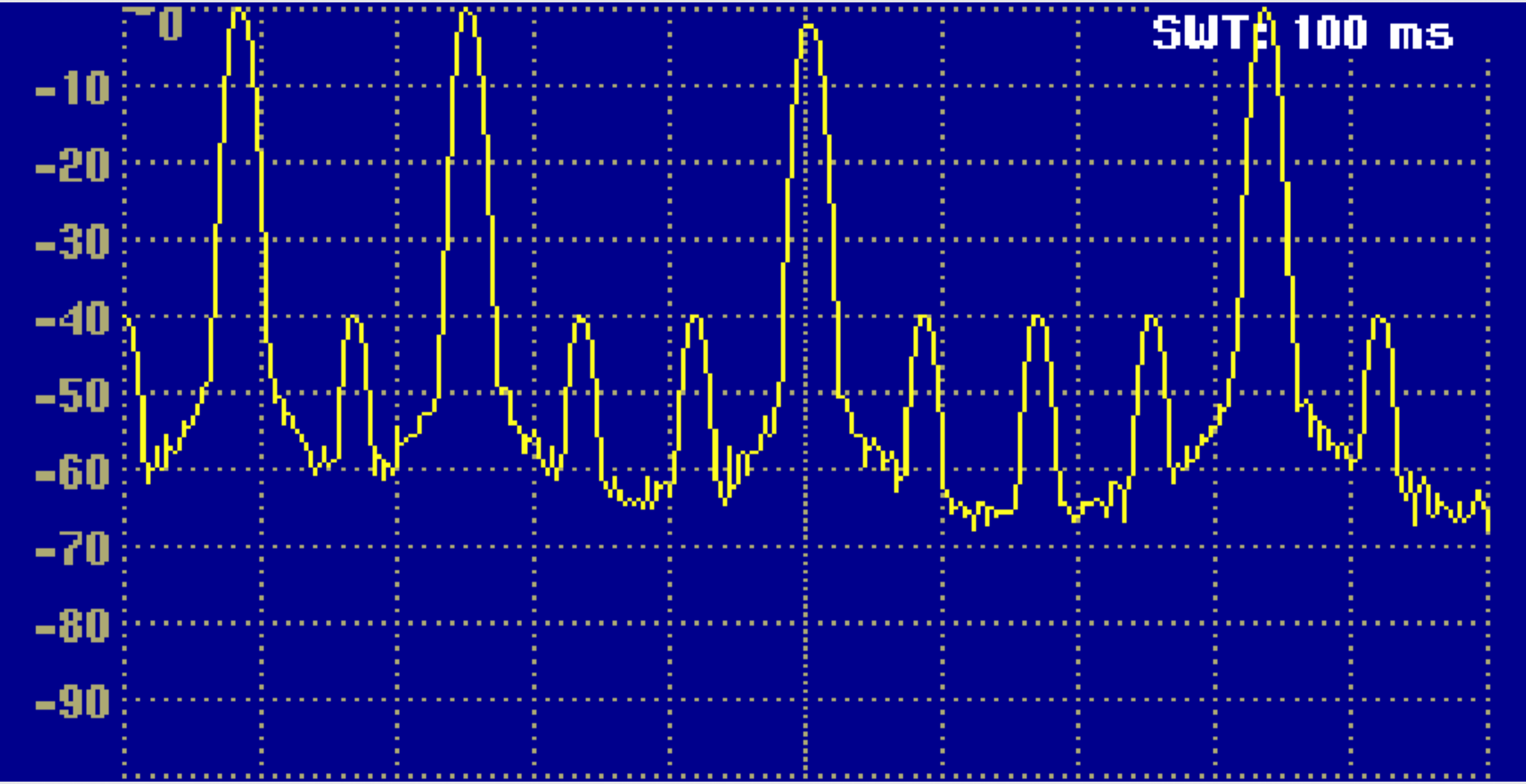
Higher linearity means lower Intermodulation between transmitters.

Intermodulation



Benefits of Digital Transmission for System Design

Typical Analog Transmitter Intermodulation



Benefits of Digital Transmission for System Design

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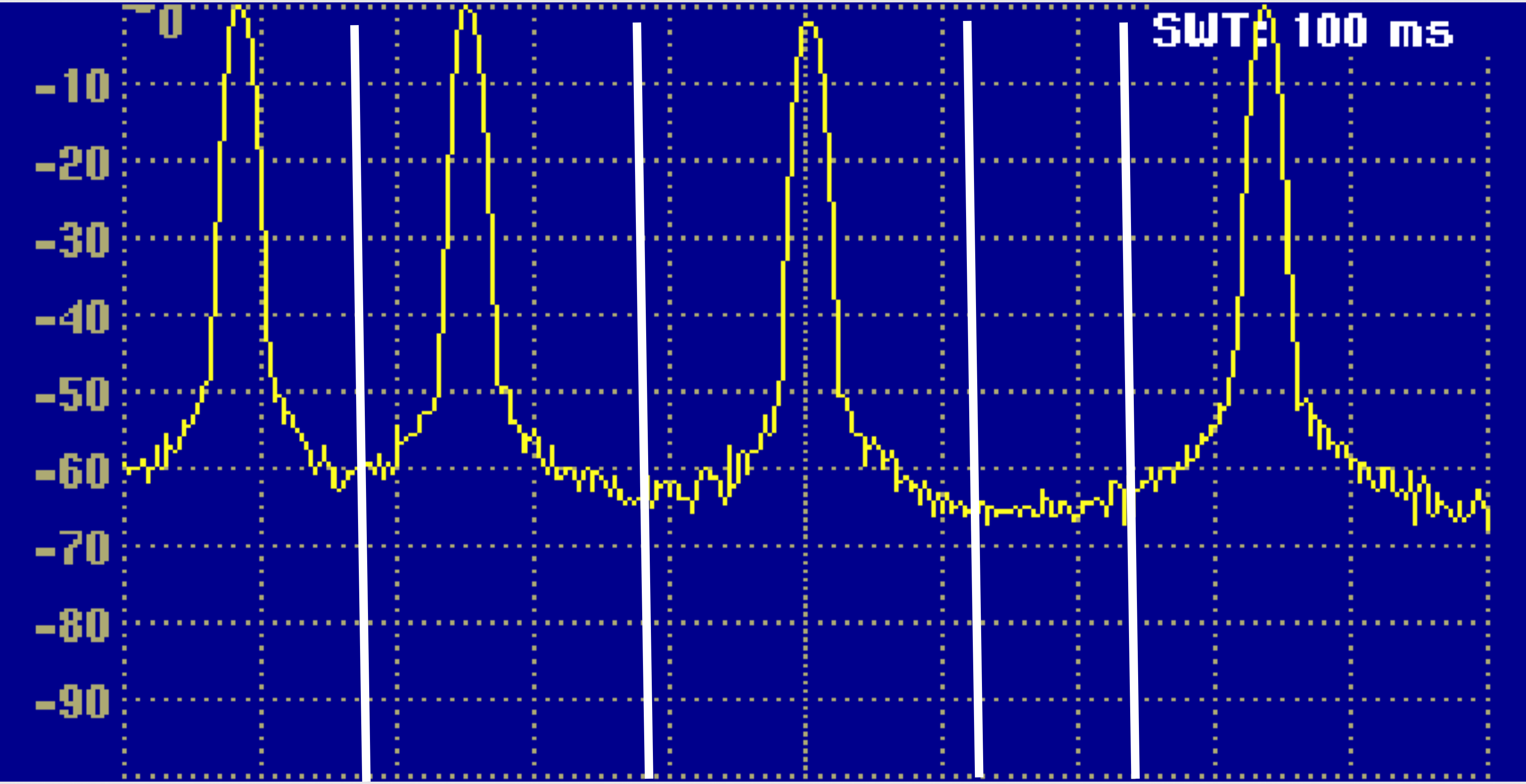
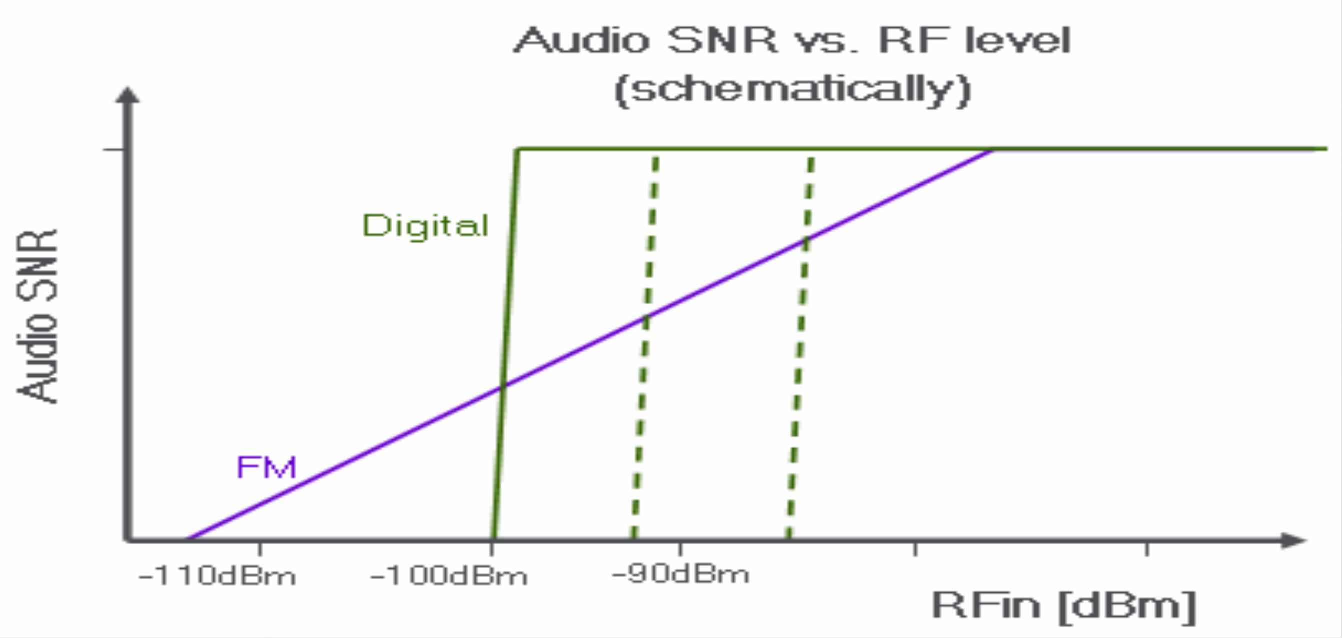
Digital Transmitters Have the Possibility of No Intermodulation



Analog systems require audio mute controlled by RF signal strength

Benefits of Digital Transmission for System Design

What about range test?
How do analog/digital transmissions act differently?



We still want best low loss cable

50 Ohm Coaxial Cable Data:

Cable Type	Frequency [MHz]	Attenuation [db/100']	Attenuation [dB/100m]	Cable diameter
RG-174/U	400 700	19.0 27.0	62.3 88.6	0.110 / 2.8
RG-58/U	400 700	9.1 12.8	29.9 42.0	0.195 / 4.95
RG-8X	400 700	6.6 9.1	21.7 29.9	0.242 / 6.15
RG-8/U	400 700	4.2 5.9	13.2 19.4	0.405 / 10.3
RG-213	400 700	4.5 6.5	14.8 21.8	0.405 / 10.3
Belden 9913	400 700	2.7 3.6	8.9 11.8	0.405 / 10.3
Belden 9913F	400 700	2.9 3.9	9.5 12.8	0.405 / 10.3

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We still have to do our home work

1. Check your local Broadcast transmitters.
   http://en-us.sennheiser.com/service-support/frequency-finder
2. Use a spectrum analyzer to sweep the location of your install.

Signal Hound

TTi PSA series

Thank You!